Winds

Classification of Winds

- Planetary winds
- seasonal winds
- periodic winds
- local winds

- Trade winds are descending and stable in areas of their origin (sub-tropical high pressure belt), and as they reach the equator, they become humid and warmer after picking up moisture on their way.
- The trade winds from two hemispheres meet at the equator, and due to convergence they rise and cause heavy rainfall.
- The eastern parts of the trade winds associated with the cool ocean currents are drier and more stable than the western parts of the ocean

Westerlies

- The westerlies are the winds blowing from the sub-tropical high pressure belts towards the sub polar low pressure belts.
- They blow from southwest to north-east in the northern hemisphere and north-west to south-east in the southern hemisphere.
- The westerlies of the southern hemisphere are stronger and persistent due to the vast expanse of water, while those of the northern hemisphere are irregular because of uneven relief of vast land-masses.
- The westerlies are best developed between 40° and 65°S latitudes. These latitudes are often called Roaring Forties, Furious Fifties, and Shrieking Sixties – dreaded terms for sailors.
- The poleward boundary of the westerlies is highly fluctuating. There are many seasonal and short-term fluctuations. These winds produce wet spells and variability in weather

Polar easterlies

- The Polar easterlies are dry, cold prevailing winds blowing from north-east to south-west direction in Northern Hemisphere and south-east to north-west in Southern Hemisphere.
- They blow from the polar high-pressure areas of the sub-polar lows.

Secondary Winds or Periodic Winds

- These winds change their direction with change in season.
- Monsoons are the best example of large-scale modification of the planetary wind system.
- Other examples of periodic winds include land and sea breeze, mountain and valley breeze, cyclones and anticyclones, and air masses.

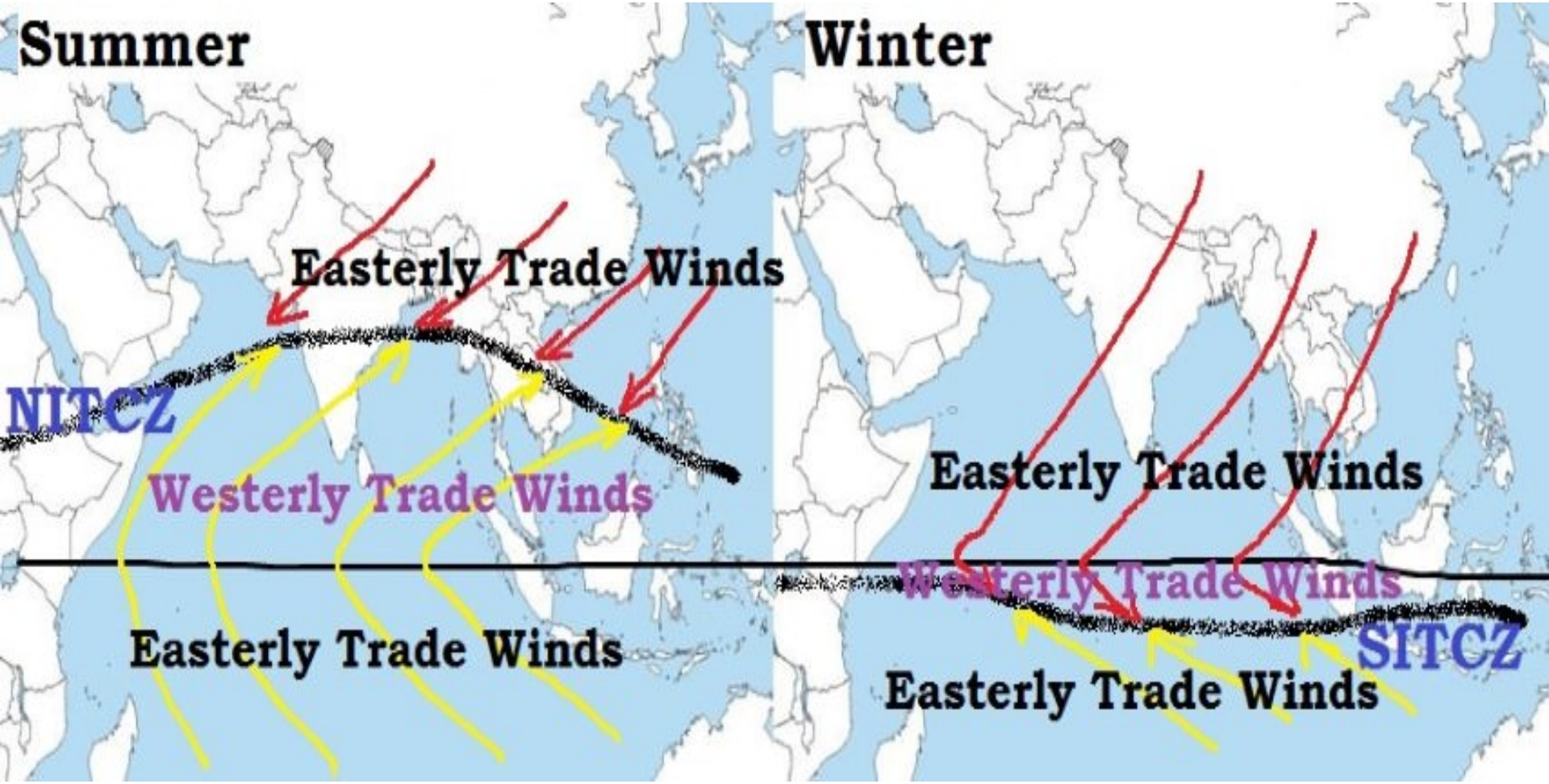
Monsoons

- Monsoons were traditionally explained as land and sea breezes on a large scale. Thus, they were considered a convectional circulation on a giant scale.
- The monsoons are characterized by seasonal reversal of wind direction.
- During summer, the trade winds of southern hemisphere are pulled northwards by an apparent northward movement of the sun and by an intense low pressure core in the north-west of the Indian subcontinent.

- While crossing the equator, these winds get deflected to their right under the effect of Coriolis force.
- These winds now approach the Asian landmass as south-west monsoons.
- Since they travel a long distance over a vast expanse of water, by the time they reach the south-western coast of India, they are over-saturated with moisture and cause heavy rainfall in India and neighboring countries.

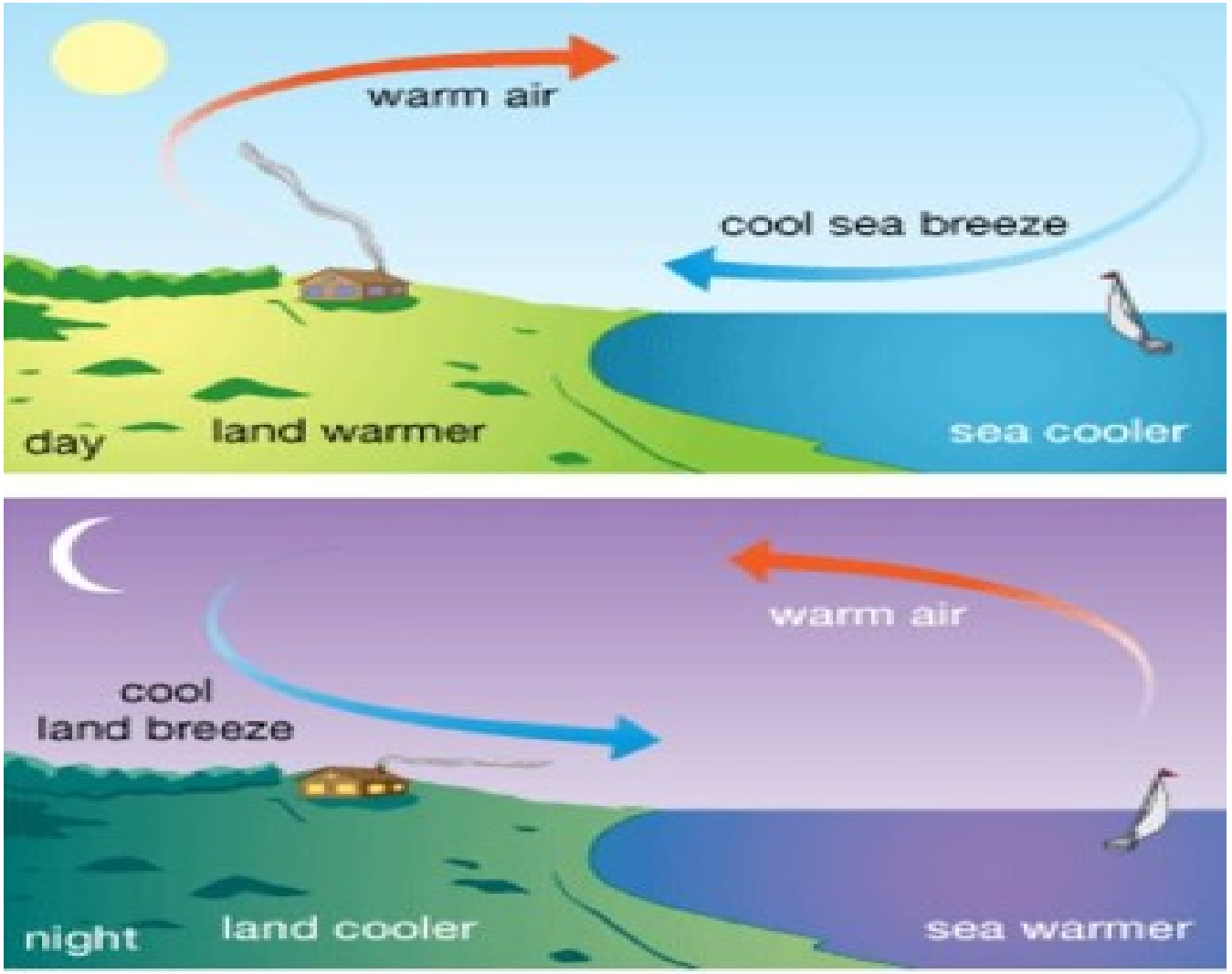
- During winter, these conditions are reversed and a high pressure core is created to the north of the Indian subcontinent.
- Divergent winds are produced by this anticyclonic movement which travels southwards towards the equator.
- This movement is enhanced by the apparent southward movement of the sun.
- These are north-east or winter monsoons which are responsible for some precipitation along the east coast of India.

- The monsoon winds flow over India, Pakistan, Bangladesh, Myanmar (Burma), Sri Lanka, the Arabian Sea, Bay of Bengal, southeastern Asia, northern Australia, China
- Outside India, in the eastern Asiatic countries, such as China and Japan, the winter monsoon is stronger than the summer monsoon.


Summer
Easterly Trade Winds
NITCZ
Westerly Trade Winds
Easterly Trade Winds
Winter
Easterly Trade Winds
Westerly Trade Winds
SITCZ
Easterly Trade Winds

Land Breeze and Sea Breeze

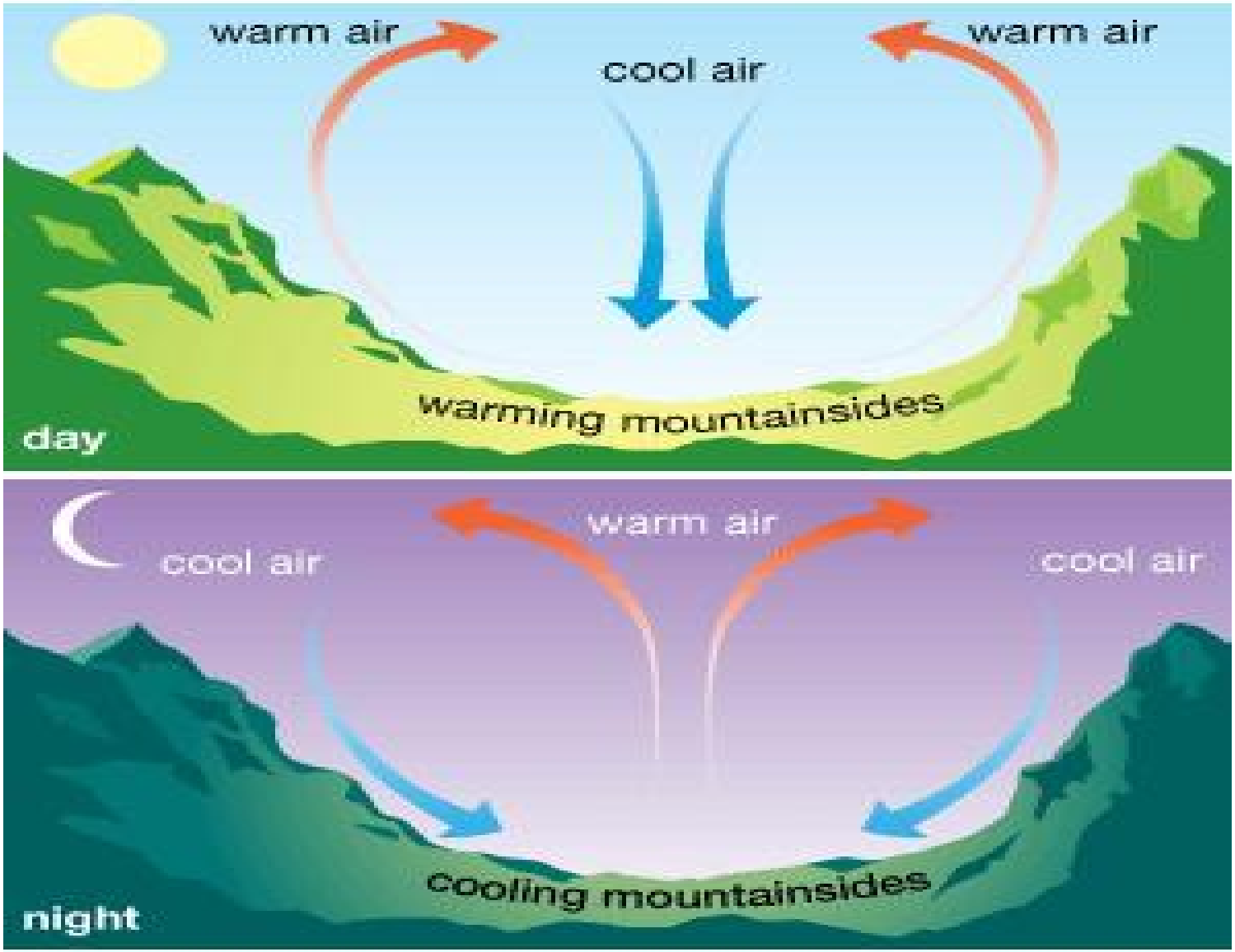
- The land and sea absorb and transfer heat differently.
- During the day the land heats up faster and becomes warmer than the sea.
- Therefore, over the land the air rises giving rise to a low pressure area, whereas the sea is relatively cool and the pressure over sea is relatively high.
- Thus, pressure gradient from sea to land is created and the wind blows from the sea to the land as the sea breeze.
- In the night the reversal of condition takes place. The land loses heat faster and is cooler than the sea.
- The pressure gradient is from the land to the sea and hence land breeze results.



Valley Breeze and Mountain Breeze

- In mountainous regions, during the day the slopes get heated up and air moves upslope and to fill the resulting gap the air from the valley blows up the valley. This wind is known as the valley breeze.
- During the night the slopes get cooled and the dense air descends into the valley as the mountain wind.
- The cool air, of the high plateaus and ice fields draining into the valley is called katabatic wind.

Valley and mountain breezes



- Another type of warm wind (katabatic wind) occurs on the leeward side of the mountain ranges.
- The moisture in these winds, while crossing the mountain ranges condense and precipitate. When it descends down the leeward side of the slope the dry air gets warmed up by adiabatic process.
- This dry air may melt the snow in a short time.

Tertiary Winds or Local Winds

- Local differences of temperature and pressure produce local winds.
- Such winds are local in extent and are confined to the lowest levels of the troposphere

Cold wind	Warm winds
❑ Pampero	❑ Foehn or Fohn
❑ Gregale	❑ Chinook
❑ Bora	❑ Zonda
❑ Tramontane	❑ Loo
❑ Mistral	❑ Sirocco


Chinook
Nor'easter
Blizzards
Norther
NORTH
AMERICA
Norte
SOUTH
AMERICA
Pampero
Helm
Mistral
Bora
Levant
Fohn
Etesians
EUROPE
Sirocco
Khamsin
Harmattan
Haboob
(Non-Directional)
Berg
AFRICA
Buran
Karaburan
ASIA
Brickfielder
Southerly
AUSTRALIA

Loo

- Harmful Wind
- In the plains of northern India and Pakistan, sometimes a very hot and dry wind blows from the west in the months of May and June, usually in the afternoons.
- It is known as Its temperature invariably ranges between 45°C and 50°C. It may cause sunstroke to people.

Foehn or Fohn

- Beneficial Wind
- Foehn is a hot wind of local importance in the
- Alps. It is a strong, gusty, dry and warm wind which develops on the leeward side of a mountain range.
- As the windward side takes away whatever moisture there is in the incoming wind in the form of orographic precipitation, the air that descends on the leeward side is dry and warm (Katabatic Wind).
- The temperature of the wind varies between 15°C and 20°C. The wind helps animal grazing by melting snow and aids the ripening of grapes.

Chinook

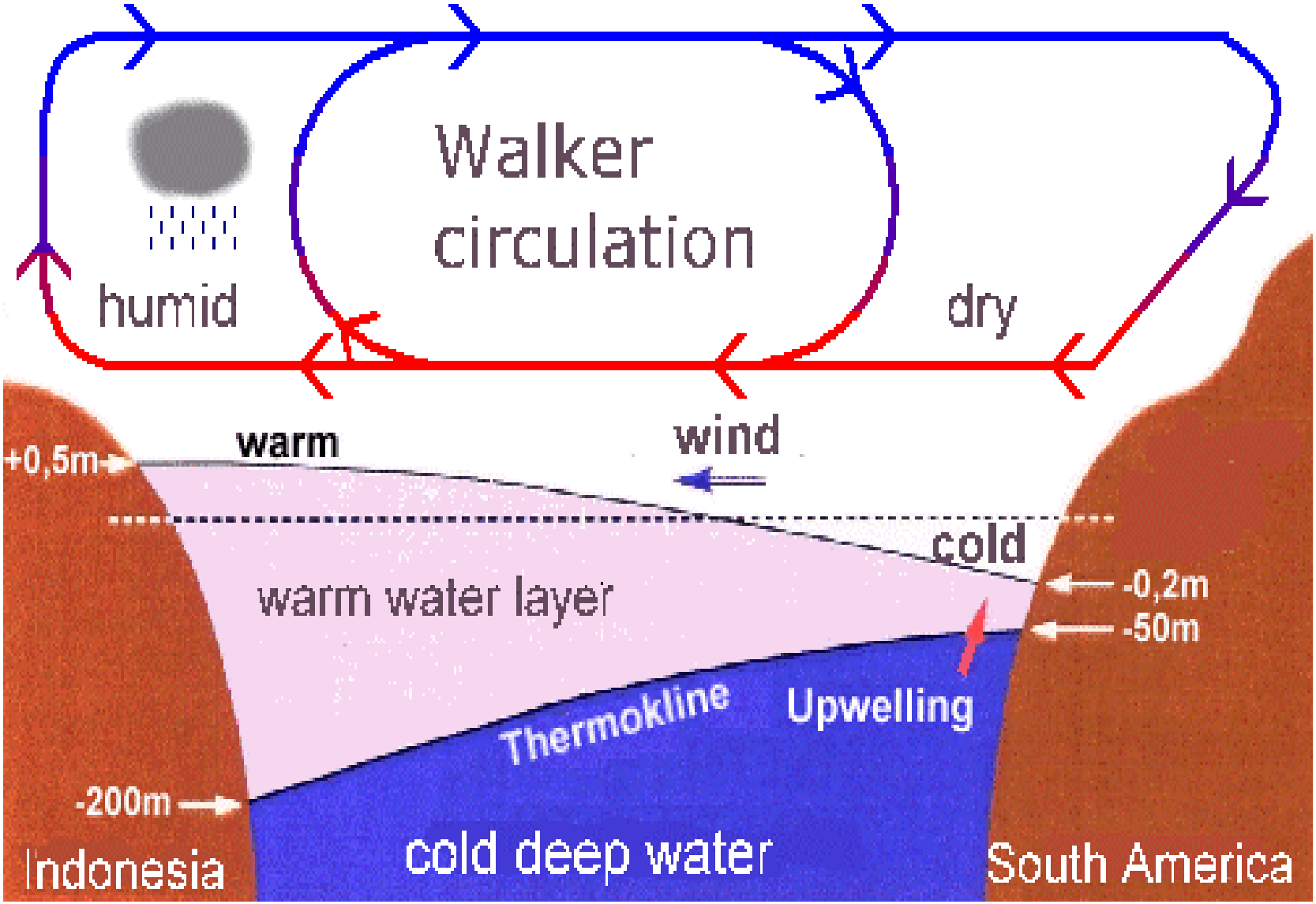
- Beneficial Wind
- Foehn like winds in USA and Canada move down the west slopes of the Rockies and are known as
- It is beneficial to ranchers east of the Rockies as it keeps the grasslands clear of snow during much of the winter.

Mistral

- Harmful Wind
- Mistral is one of the local names given to such winds that blow from the Alps over France towards the Mediterranean Sea.
- It is channeled through the Rhine valley.
- It is very cold and dry with a high speed.
- It brings blizzards into southern France.

Walker circulation

- The Walker circulation (walker cell) is caused by the pressure gradient force that results from a high pressure system over the eastern Pacific ocean, and a low pressure system over Indonesia
- The Walker cell is indirectly related to upwelling off the coasts of Peru and Ecuador. This brings nutrient-rich cold water to the surface, increasing fishing stocks.


Walker
circulation
humid
dry
warm
wind
+0,5m
cold
warm water layer
-0,2m
-50m
Thermokline
Upwelling
-200m
Indonesia
cold deep water
South America

El Nino

- El Niño is the name given to the occasional development of warm ocean surface waters along the coast of Ecuador and Peru.
- When this warming occurs the usual upwelling of cold, nutrient rich deep ocean water is significantly reduced.
- El Niño normally occurs around Christmas and usually lasts for a few weeks to a few months.
- Sometimes an extremely warm event can develop that lasts for much longer time periods. In the 1990s, strong El Niños developed in 1991 and lasted until 1995, and from fall 1997 to spring 1998.

Normal Conditions

- In a normal year, a surface low pressure develops in the region of northern Australia and Indonesia and a high pressure system over the coast of Peru.
- As a result, the trade winds over the Pacific Ocean move strongly from east to west.
- The easterly flow of the trade winds carries warm surface waters westward, bringing convective storms (thunderstorms) to Indonesia and coastal Australia.
- Along the coast of Peru, cold bottom cold nutrient rich water wells up to the surface to replace the warm water that is pulled to the west.

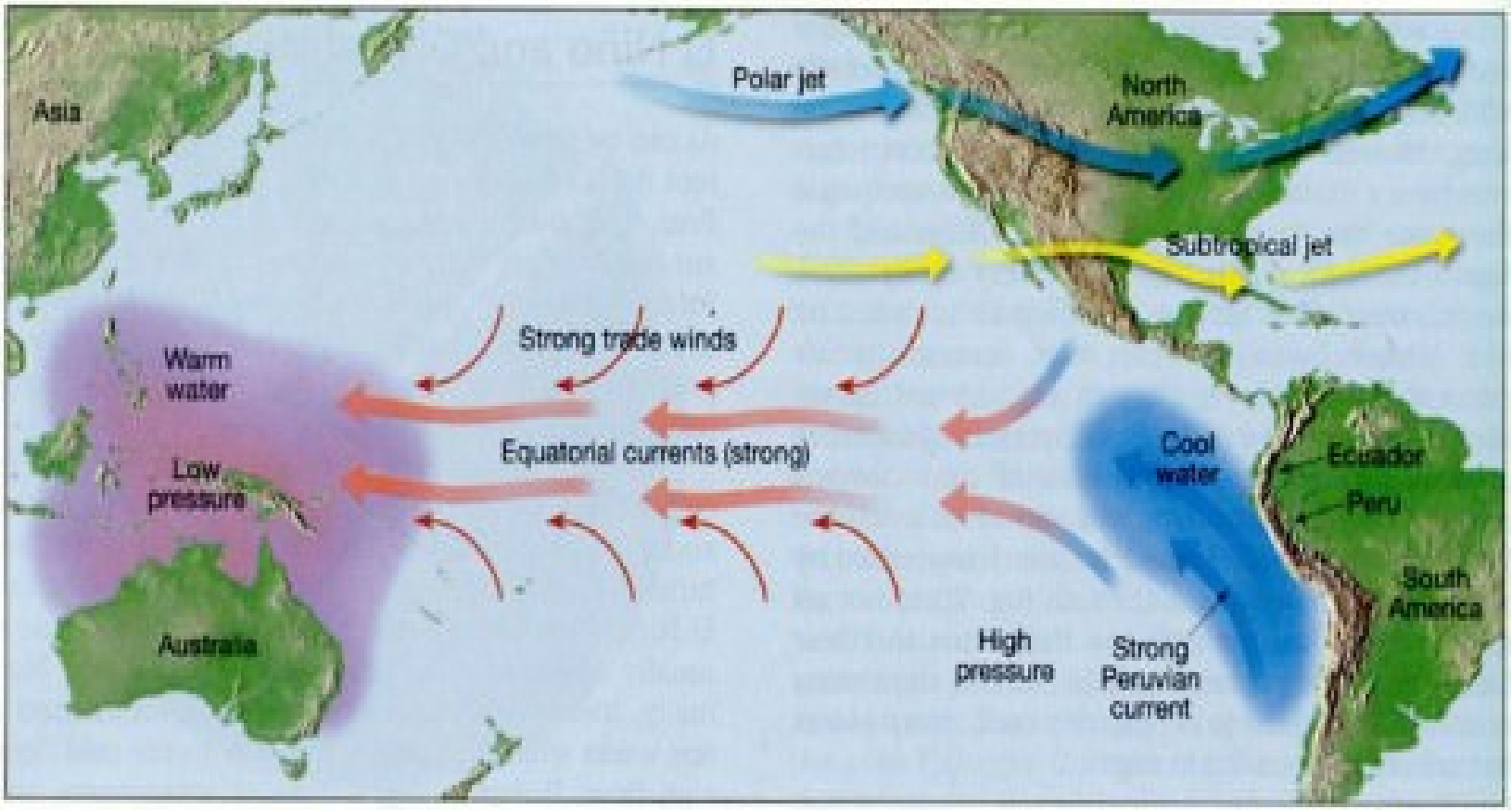


Fig.6 Normally, the trade winds and strong equatorial currents flow toward the west. At the same time, an intense Peruvian current causes upwelling of cold water along the west coast of South America.

During El Nino year

- In an El Niño year, air pressure drops over large areas of the central Pacific and along the coast of South America.
- The normal low pressure system is replaced by a weak high in the western Pacific (the southern oscillation).
- This change in pressure pattern causes the trade winds to be reduced == Weak Walker Cell. Sometimes Walker Cell might even get reversed.
- This reduction allows the equatorial counter current (current along doldrums) to accumulate warm ocean water along the coastlines of Peru and Ecuador.

- This accumulation of warm water causes the thermocline to drop in the eastern part of Pacific Ocean which cuts off the upwelling of cold deep ocean water along the coast of Peru.
- Climatically, the development of an El Niño brings drought to the western Pacific, rains to the equatorial coast of South America, and convective storms and hurricanes to the central Pacific.

Effects of El Nino

- The warmer waters had a devastating effect on marine life existing off the coast of Peru and Ecuador.
- Fish catches off the coast of South America were lower than in the normal year (Because there is no upwelling).
- Severe droughts occur in Australia, Indonesia, India and southern Africa.
- Heavy rains in California, Ecuador, and the Gulf of Mexico.

How El Nino impacts monsoon rainfall in India

- El Nino and Indian monsoon are inversely related.
- The most prominent droughts in India – six of them – since 1871 have been El Nino droughts, including the recent ones in 2002 and 2009
- However, not all El Nino years led to a drought in India. For instance, 1997/98 was a strong El Nino year but there was no drought (Because of IOD).

- On the other hand, a moderate El Nino in 2002 resulted in one of the worst droughts.
- El Nino directly impacts India’s agrarian economy as it tends to lower the production of summer crops such as rice, sugarcane, cotton and oilseeds.
- The ultimate impact is seen in the form of high inflation and low gross domestic product growth as agriculture contributes around 14 per cent to the Indian economy.

El Nino Southern Oscillation [ENSO]

- The formation of an El Niño [Circulation of Water] is linked with Pacific Ocean circulation pattern known as the southern oscillation

- El Nino and Southern Oscillation coincide most of the times hence their combination is called ENSO – El Nino Southern Oscillation.

- Only El Nino == [Warm water in Eastern Pacific + Cold water in Western Pacific].

- Only SO == [Low Pressure over Eastern Pacific + High Pressure over Western Pacific]

- ENSO = [Warm water in Eastern Pacific + Low Pressure over Eastern Pacific] + [Cold water in Western Pacific + High Pressure over Western Pacific].

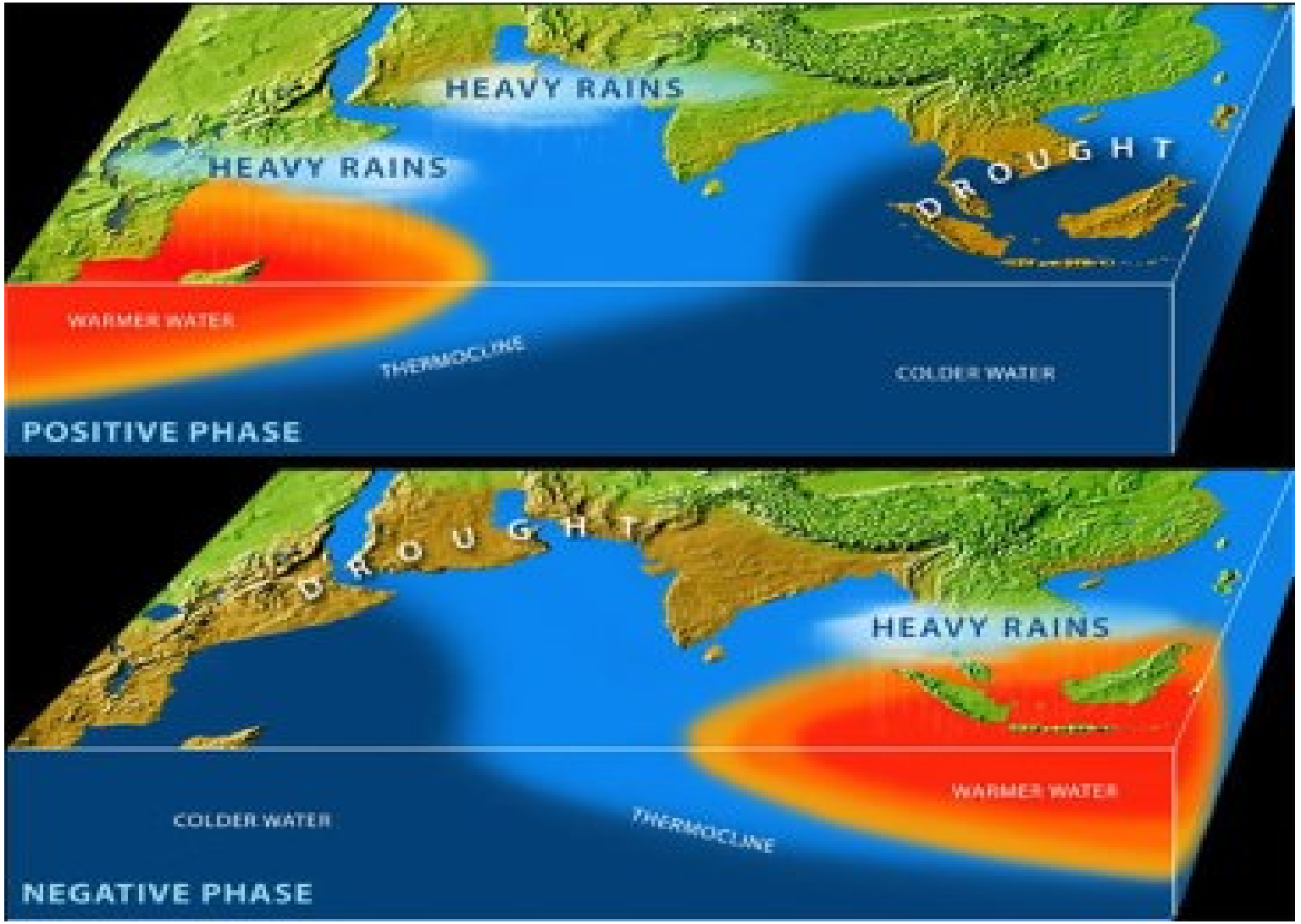
La Nina

- After an El Niño event weather conditions usually return back to normal.
- However, in some years the trade winds can become extremely strong and an abnormal accumulation of cold water can occur in the central and eastern Pacific. This event is called a La Niña.
- A strong La Niña occurred in 1988 and scientists believe that it may have been responsible for the summer drought over central North America. During this period, the Atlantic Ocean has seen very active hurricane seasons in 1998 and 1999.
- One of the hurricanes that developed, named Mitch, was the strongest October hurricane ever to develop in about 100 years of record keeping.

Indian Ocean Dipole

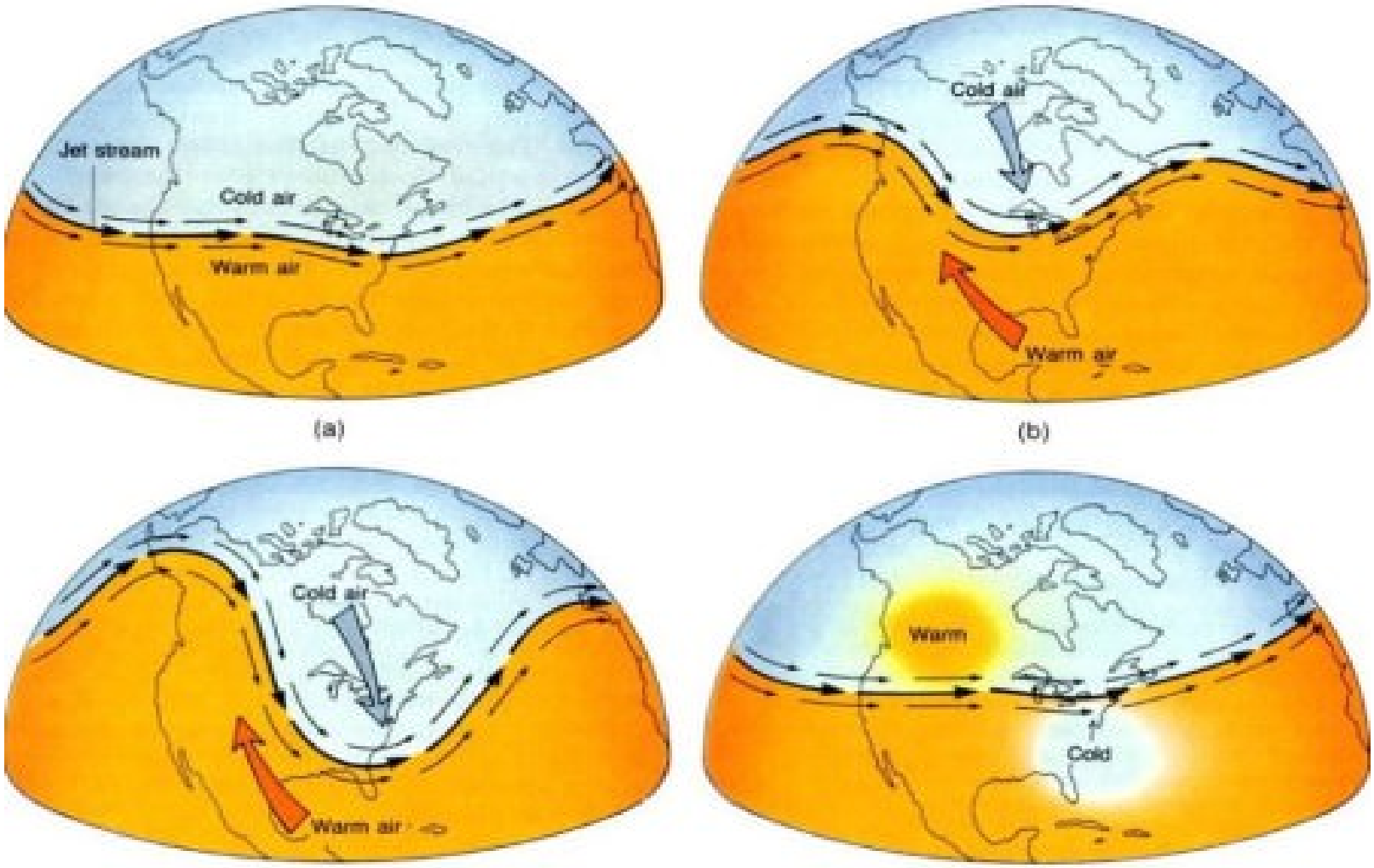
- The Indian Ocean Dipole (IOD) is defined by the difference in sea surface temperature between two areas (or poles, hence a dipole) – a western pole in the Arabian Sea (western Indian Ocean) and an eastern pole in the eastern Indian Ocean south of Indonesia.
- IOD develops in the equatorial region of Indian Ocean from April to May peaking in October.

- With a positive IOD winds over the Indian Ocean blow from east to west (from Bay of Bengal towards Arabian Sea).
- This results in the Arabian Sea (western Indian Ocean near African Coast) being much warmer and eastern Indian Ocean around Indonesia becoming colder and dry.
- In the negative dipole year (negative IOD), reverse happens making Indonesia much warmer and rainier.


HEAVY RAINS
HEAVY RAINS
DROUGHT
WARMER WATER
THERMOCLINE
COLDER WATER
POSITIVE PHASE
DROUGHT
HEAVY RAINS
COLDER WATER
THERMOCLINE
WARMER WATER
NEGATIVE PHASE

Rossby Waves

- The meandering jet streams are called Rossby Waves.
- Rossby waves are natural phenomenon in the atmosphere and oceans due to rotation of earth.
- In planetary atmospheres, they are due to the variation in the Coriolis effect (When temperature contrast is low, speed of jet stream is low, and Coriolis force is weak leading to meandering) with latitude.
- Rossby waves are formed when polar air moves toward the Equator while tropical air is moving poleward.
- The existence of these waves explains the low-pressure cells (cyclones) and high-pressure cells (anticyclones).


Jet stream
Cold air
Warm air
(a)
Cold air
Warm air
(b)
Cold air
Warm air
Warm
Cold