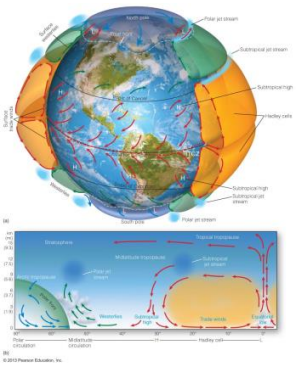
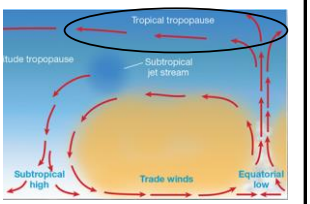
Global Atmospheric Circulation (Continued)

- Intertropical Convergence Zone
- Trade Winds
- Subtropical Highs
- Westerlies
- Subpolar Lows
- Polar Front
- Polar High
- Polar Easterlies
- Geostrophic Winds
- Jet Streams



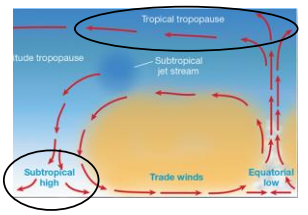
Air Aloft Moves Towards Poles

- Rising air within ITCZ, once aloft, moves towards the poles
- This poleward-moving air, however, must converge aloft because the earth is a sphere



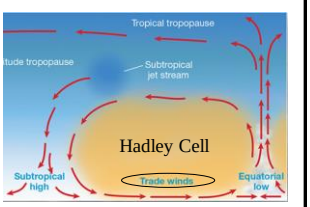
Air Aloft Moves Towards Poles

- Air aloft also radiates energy into outer space, cools, and becomes denser, causing it to sink in regions known as Subtropical Highs

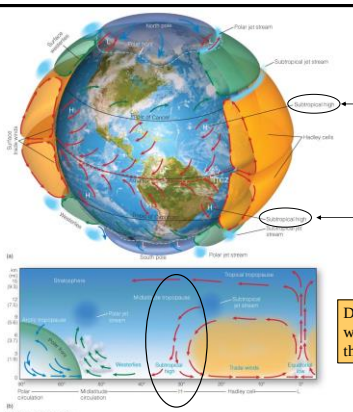


Air Aloft Moves Towards Poles

- Some of the sinking air returns to the equator as trade winds via Hadley Cell circulation
- Some sinking air also blows northward to become the Westerlies

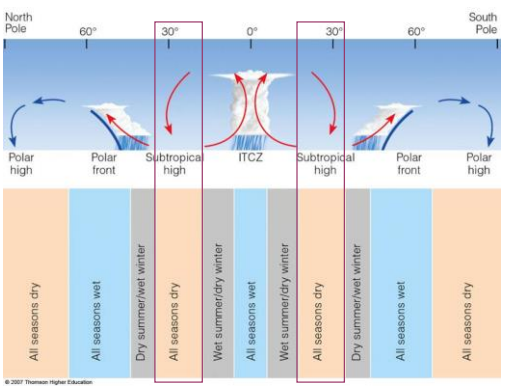


Subtropical Highs

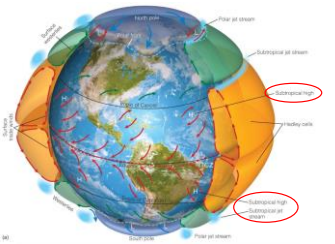


Regions of sinking air at ~30° north and south latitudes are known as Subtropical Highs

Descending air becomes warmer and drier towards the surface

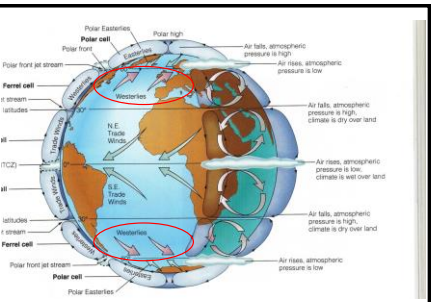


Subtropical Highs Also Known As "Horse Latitudes"



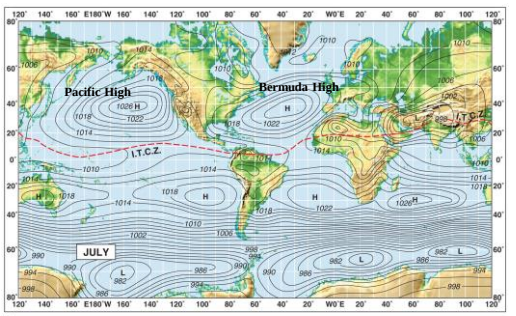
- One theory on the origin of the name:
  - Ships sailing to America often languished here due to lack of winds
  - When food supplies diminished, horses were either eaten or thrown overboard to lighten load, hence the term "horse latitudes"

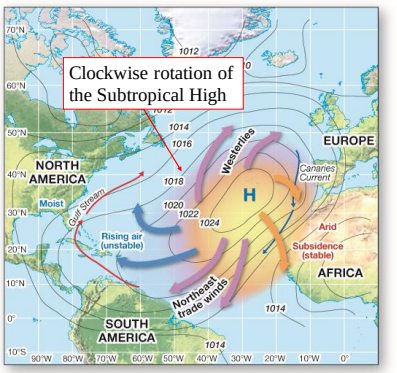
Westerlies

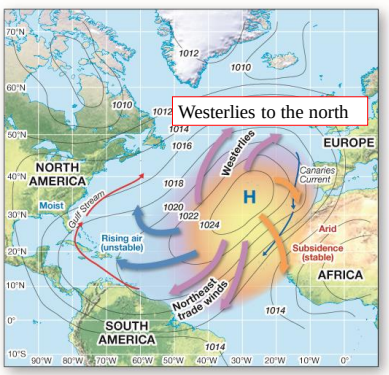


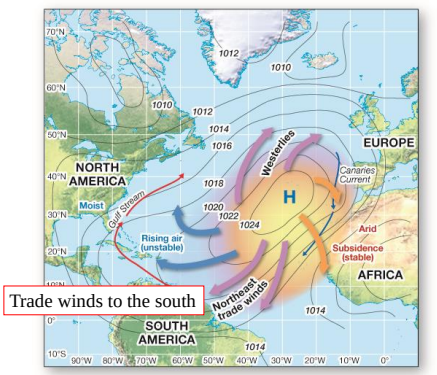
- The Westerlies are winds that occur at higher latitudes than the trade winds
- In northern hemisphere, westerlies mainly blow from the west towards the northeast:
  - Utilized by sailors returning to Europe from North America

Subtropical High-Pressure Cells

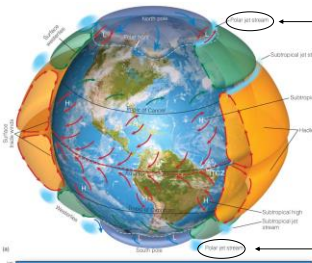






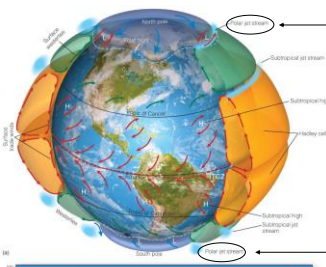


Strong Bermuda High steers Atlantic hurricanes into the Gulf while weak High steers hurricanes up the East Coast



Polar Front where warm air rises over cold air

- Polar front is the area of contrast between cold and warm air masses
- The warmer Westerlies rise over cold Polar Easterlies to create low-pressure cells
- Site of the polar jet stream

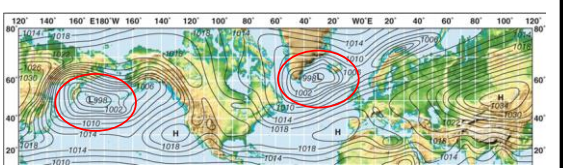


Polar Front where warm air rises over cold air

Polar Front where warm air rises over cold air

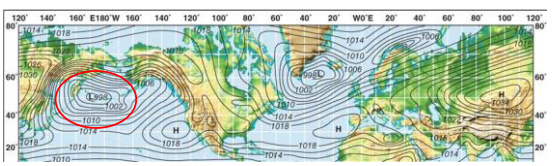
Uplift of warm, moist air results in cloud formation and precipitation

Subpolar Low-Pressure Cells



- In winter, two low-pressure cells dominate around 60º N latitude but weaken or disappear in summer

Subpolar Low-Pressure Cells



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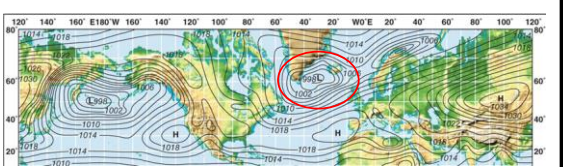
- The Aleutian Low in the north Pacific generates storms and cyclonic systems that then migrate eastward across North America:
  - Most active during late fall to late spring

Subpolar Low-Pressure Cells



- In winter, two low-pressure cells dominate around 60º N latitude but weaken or disappear in summer
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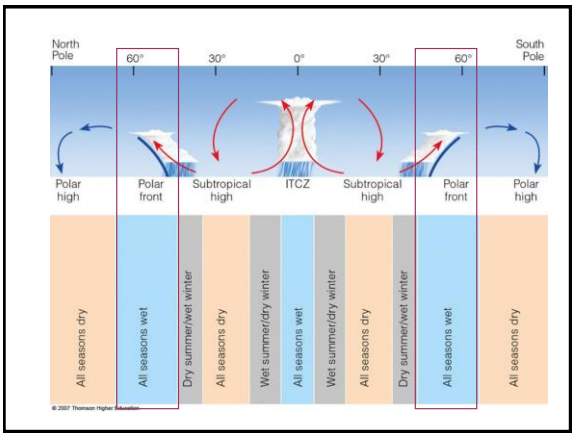
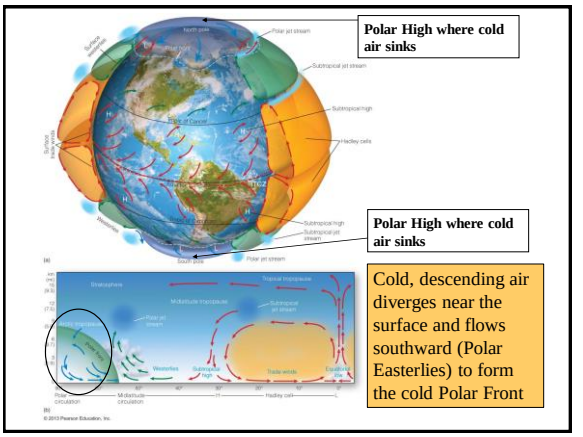
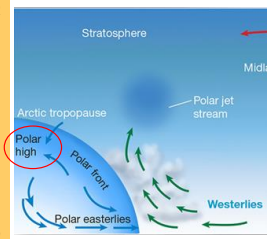
- Icelandic low produces winter winds over the North Atlantic

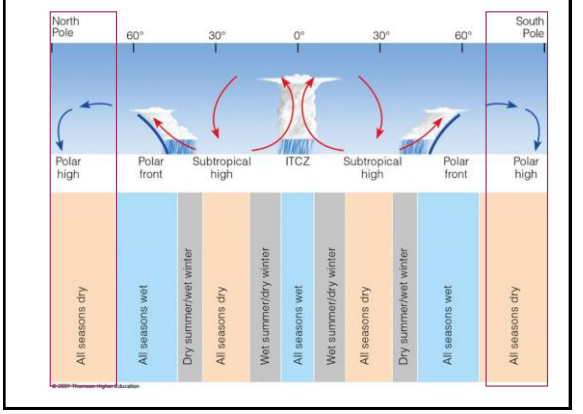




Polar High-Pressure Cells

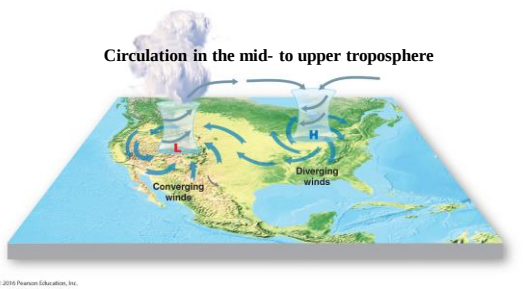
- Polar atmospheric masses are small and receives little energy from the Sun
- Arctic High forms in the Northern Hemisphere; Antarctic High in Southern Hemisphere
- Arctic High tends to form over continental areas in winter (Canadian and Siberian highs):
  - Less pronounced than the Antarctic High
  - Cold air aloft sinks towards the surface
  - Descending winds diverge clockwise near the surface to form the Polar Easterlies and Polar Front



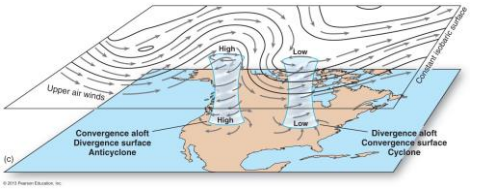


Global Wind Patterns

Geostrophic Winds

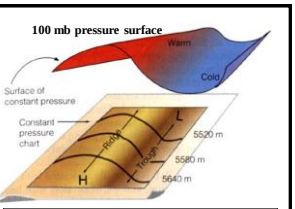


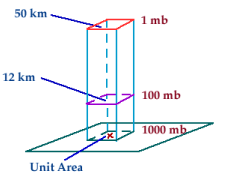
Upper Tropospheric Circulation

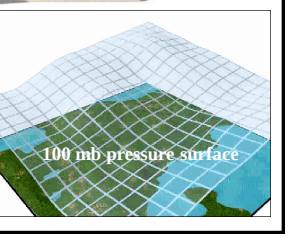


- Circulation in the middle and upper troposphere generates geostrophic winds
- Upper tropospheric circulation can be visualized by viewing a constant isobaric (pressure) surface

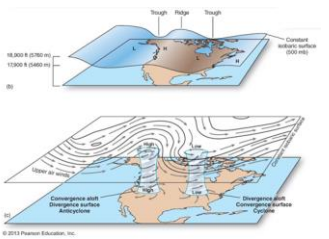
Isobaric (Pressure) Surfaces Are Planes That Connect Points Of Equal Atmospheric Pressure





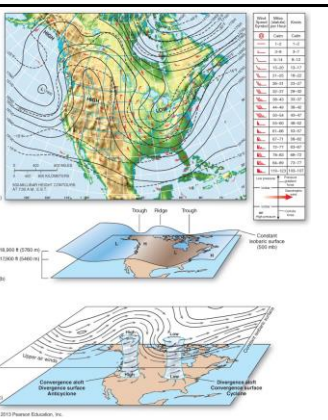


Upper Tropospheric Circulation



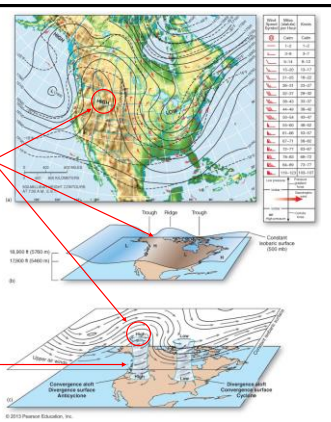
- An isobaric (pressure) surface for the mid- to upper troposphere undulates:
  - Forms ridges of high pressure where winds slow and converge (pile up) in anticyclonic motion
  - Forms troughs of low pressure where winds accelerate and diverge in cyclonic circulation

Constant Isobaric Surface (500 Mb) For An April Day Showing Circulation In The Upper Atmosphere



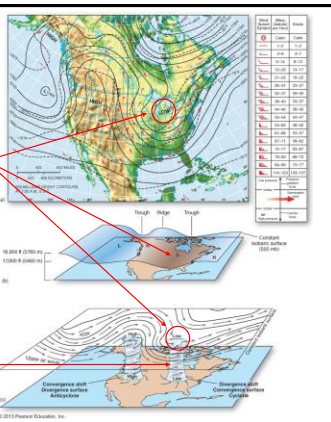
High-pressure area appears as a ridge. Upper (geostrophic) winds circulate around it in a clockwise flow

Air sinks and diverges in clockwise flow near surface



Low-pressure area appears as a trough. Upper (geostrophic) winds circulate around it in a counterclockwise flow

Surface winds converge in counterclockwise flow, ascend, and diverge aloft

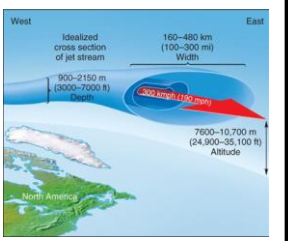


Jet Streams

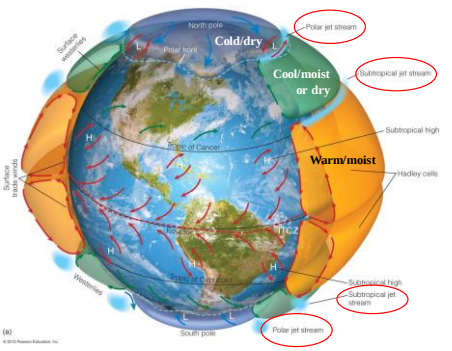
- A jet stream is a region or band of high winds in the upper troposphere (where jets fly)
- Two major jet streams (polar and subtropical) circle the earth at the mid-latitudes (30º to 60º N and S)
- Jet streams wander, thus having a big influence on the development and intensification of storms

What Causes a Jet Stream?

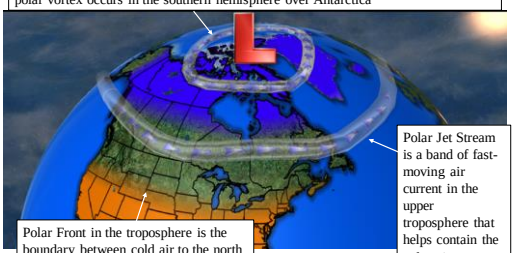
- The basic cause of the two jet streams is the rapid change in atmospheric temperature in the middle latitudes:
  - Cold, dense air mass to the north
  - Warm, moist air mass to the south
- Jet streams are most intense in the winter when the temperature contrast is greatest



Jet Streams Form at Boundaries of Contrasting Air Masses

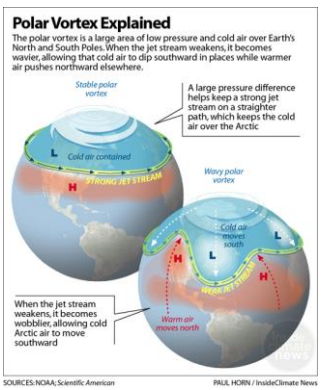


The North Polar Vortex is a band of strong westerly (counterclockwise flowing) winds in the stratosphere that enclose a large pool of extremely cold air: A stronger polar vortex occurs in the southern hemisphere over Antarctica

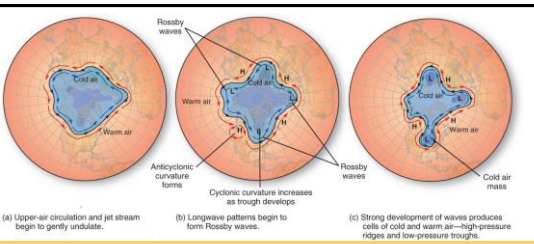


Polar Jet Stream is a band of fast-moving air current in the upper troposphere that helps contain the polar air mass

Polar Front in the troposphere is the boundary between cold air to the north and warmer air at lower latitudes



- Stratospheric warming of the Polar Vortex can weaken the polar jet stream, allowing cold Arctic air to push southward
- Warming of the Arctic due to climate change also weakens the polar jet stream by reducing the temperature contrast between the two air masses



- Rossby waves develop within the geostrophic (upper troposphere) circulation pattern in relation to polar jet-stream flow:
  - Weakened jet stream undulates and brings tongues of cold air southward as warmer tropical air moves northward
  - Form cells of warm air around high-pressure ridges and cold air around low pressure troughs
  - Support development of cyclonic storm systems at the surface

Jet Stream_Rossby Waves

Local Winds

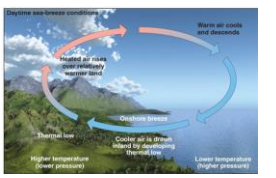
- **Land-sea breezes**
- **Mountain-valley breezes**
- **Katabatic winds**
- **Monsoonal winds**

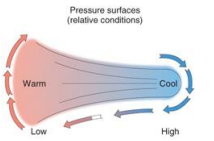
Land-Sea Breezes

- If two nearby regions on the earth's surface are heated differently…
  - The result is a temperature (hence density) difference in the atmosphere
  - Winds will result because of the density difference.
- Warm, less dense air rises next to cool denser air, which sinks.

Land-Sea Breezes

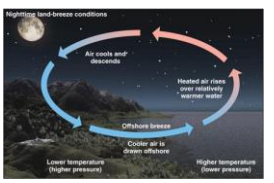
- During the day, land heats up faster than water
- Pressure surfaces puff-up over land
- Warm-air rises over land, drawing in cooler surface air from water
- Surface breeze blows landward

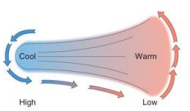




Land-Sea Breezes

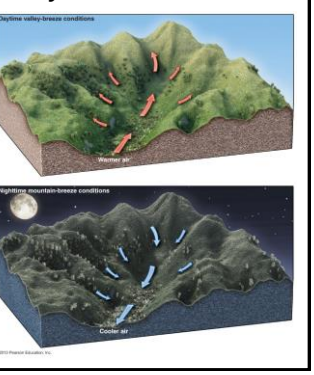
- At night, land cools faster than water
- Pressure surfaces puff-up over warmer water
- Warm-air rises over water, drawing in cooler surface air from land
- Surface breeze blows seaward





Mountain-Valley Breezes

- During the day, valley air heats rapidly:
  - Warm air rises upslope
- Mountain air cools rapidly at night:
  - Cooler air subsides down-slope into the valley



Katabatic Winds

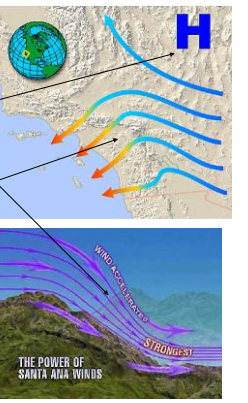
- Katabatic winds are stronger and occur on a larger scale than mountain-valley breezes
- Layers of air at the surface of a highland or plateau cools, becomes denser, and flows down-slope
- Examples:
  - Ferocious winds blowing off ice sheets of Antarctica and Greenland
  - Santa Ana winds of California

Santa Ana Winds Are Often In Force During Wildfire Season

Strong, dry winds generated by high pressure over the Great Basin of western U.S. flow out across the desert towards southern California

Winds blowing over the Sierra Nevada Mountains then flow downslope to lower elevations towards the coast

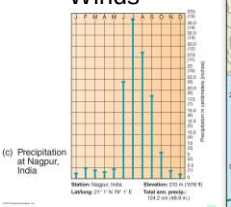
Downslope-flowing winds are heated at lower elevations by atmospheric compression; winds also increase in speed through constricting valleys

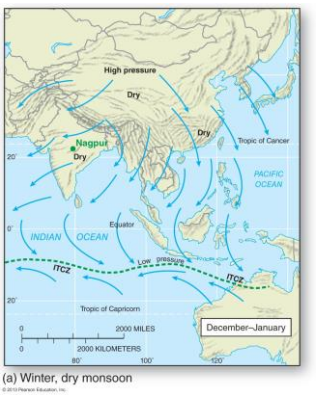


Monsoonal Winds

- Most notable in India, parts of Indochina, and Philippines.
- During the cooler winter, stable high pressure forms over the continent to produce a long, dry season.
- By mid-summer, continental interior heats up, creating low pressure area that draws in air from surroundings:
  - Incoming moist air from Indian Ocean brings in torrential rains (up to 400 inches every summer).
  - Flooding can be destructive, but are important for crops.

Monsoonal Winds

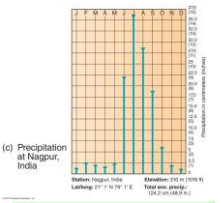


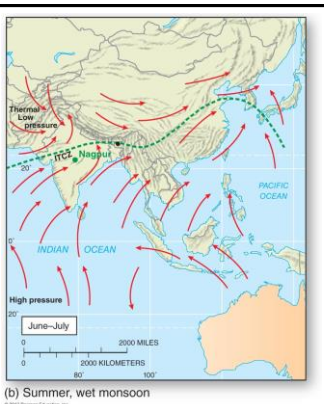


(a) Winter, dry monsoon

In winter, land is cooler than ocean; High pressure over land causes air to sink; Surface winds blow away from land towards ocean; Land is dry

Monsoonal Winds





(b) Summer, wet monsoon

In summer, land heats up faster than ocean. Rising air over land draws warm, moist surface winds inland from the ocean. Land is drenched in rain

End Lecture 4b