Lesson 21: Weather

■ Learning Objectives:

- Know the principles of basic weather phenomenon, including fronts, subtropical and tropical storms.
- Know the relationship between wind and current in a wind-driven current system.
- Know the earth's major wind and current systems.
- Know how wind velocities relate to storm warnings and their effects on sea state.
- Know the sources of environmental predictions including pilot charts and weather broadcasts.
- Know the characteristics of the approach of tropical storms and hurricane/typhoon evasion techniques.
- Applicable Reading: Surface Ship Operations, pp. 75-104.

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- **Air Flow**
  - The general flow of air air about the planet is caused by temperature differentials. The air at the earth's equators receives much more heat than the air at the poles. Consequently, the warmer air rises and is displaced by the colder, more dense air from the poles. This creates a North-South flow of air.
  - The North-South flow of air is complicated by the rotation of the earth. The rotation of the earth creates the Coriolis Force which tends to deflect objects in motion. This deflection is known as the Coriolis Effect, combined with the North-South movement, causes the various prevailing wind belts.
    - The Coriolis Effect also affects air circulation around low pressure areas. Low pressure areas in the Northern Hemisphere are subject to counter-clockwise circulation of fluids while in the Southern Hemisphere fluids circulate clockwise.
    - Permanent pressure areas around the world have been created by the Coriolis Effect as shown below.
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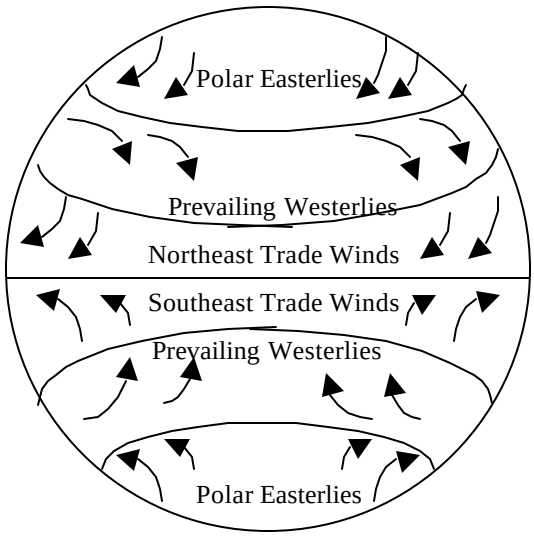

(Overhead 21-1)

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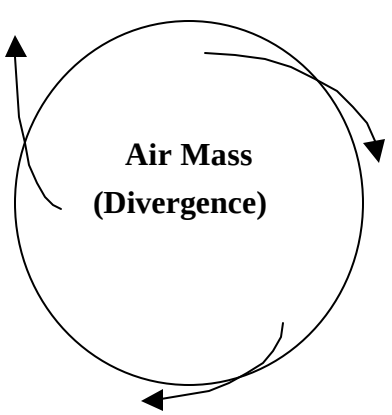
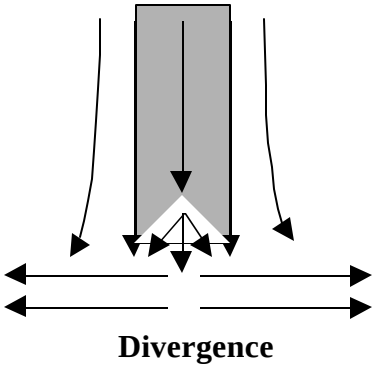
- **Pressure Systems**
  - High pressure Systems
    - High pressure areas (anticyclones) are areas that have a pressure that is high relative to the surroundings. These areas are formed when air from a higher altitude is pulled down into a diverging air mass (an air mass where the wind is f lowing outward). The descending air is warmed, and consequently, its capacity to hold moisture increases. This increased ability to hold moisture results in the dissipation of clouds and conditions favorable to clear weather.





(Overhead 21-2)

    - Low pressure systems
      - Low pressure areas (cyclones) are created by converging winds. The upward moving air is cooled and results in conditions that are favorable to stormy weather. Converging winds are often caused by two air masses of different temperatures and densities meeting.

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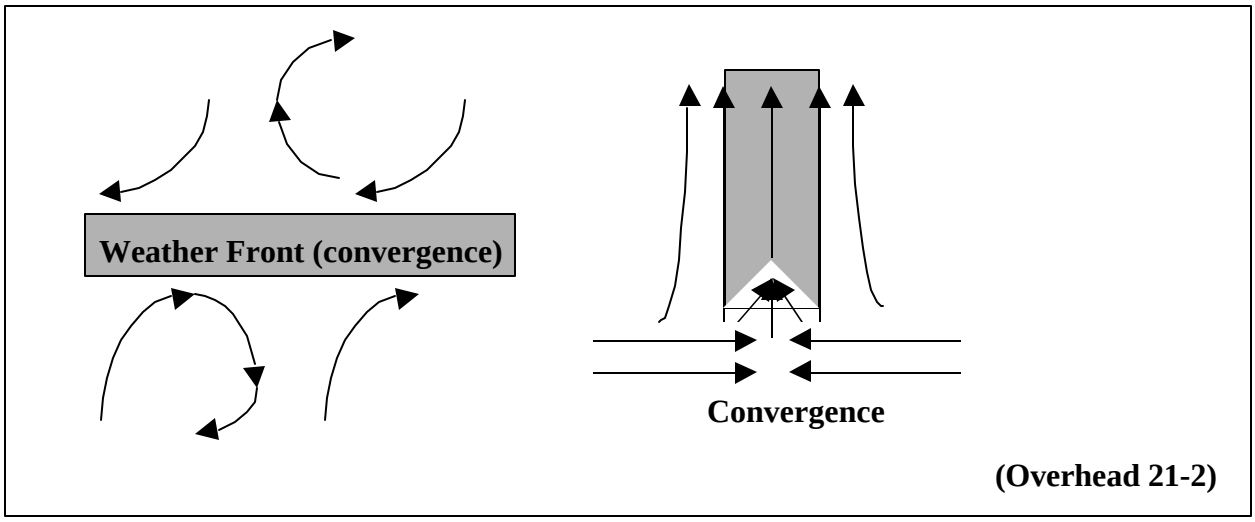
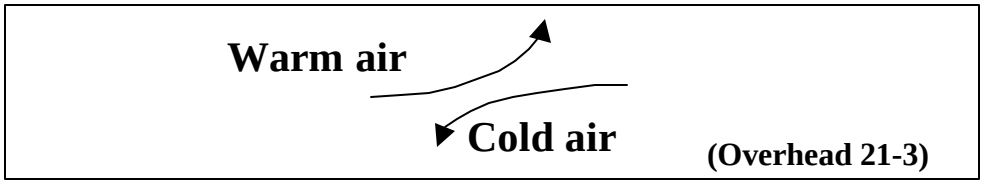


- **Fronts**
  - High pressure and low pressure systems travel from the areas where they were created. When air masses meet, they 'compete' for dominance. The boundary zone between two meeting air masses is know as a front.
  - Cold front - The boundary between cold and warm air masses where cold air is displacing warm air.
    - Rapid moving cold front (15-30 kts) . The quickly moving cold air displaces the warm air by vigorously forcing it up (the steep slope of the front lifts the warm up quickly). Narrow bands of precipitation and strong thunderstorms are often created in the immediate vicinity of the front.



    - Slow moving cold front (5-15 kts) - The displacement of the warm air is less severe (the front has a more gradual slope). Precipitation

and some thunderstorm activity are created over a larger area.

- Squall line - Severe thunderstorms may form if cold air from a rapid moving front rushes down into a warm air mass.
- Cirrostratus and cirrus clouds will be the first indication of an approaching cold front.
- Wind
  - In the Northern Hemisphere, winds are southerly ahead of the front and northerly behind the front. The opposite is true for the Southern Hemisphere.
  - A distinct shift in winds will occur when frontal passage occurs. In the Northern hemisphere winds will shift from southerly to northerly and in the Southern Hemisphere they will shift from northerly to southerly).
- Pressure - a fall in pressure will precede the front. A gradual rise will indicate the front's passage.

- Warm front (10-20 kts) - The boundary between cold and warm air masses where warm air is displacing cooler air.
  - Warm air is not actually forcing cold air to move. The warm air is filling in behind cold air that is moving out of the area (there is no forced movement). Some mixing of the two air masses does occur as some of the warmer air moves over the colder air. This interaction produces steady precipitation over a large area (up to 300 miles ahead of the front).
  - Cirrus and Cirrostratus clouds precede the front (up to 1000 miles ahead of the front), normally followed by stratus clouds and fog .
  - Winds
    - Southerly winds precede and follow the front in the Northern

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Hemisphere. Northerly winds precede and follow in the Southern Hemisphere.

- A shift from southeasterly to southwesterly (in the Northern Hemisphere) indicates the passage of the front.
- Pressure - a steady fall will precede the front. A leveling off will occur after frontal passage.

- Occluded front - A boundary that occurs when a cold front completely lifts a warm front up off of the earth's surface. This situation creates a mix of weather patterns that are associated with warm fronts and cold fronts. A wide spread area of precipitation, clouds and fog (warm front) combined with a contained area of severe weather often results. This situation generally lasts only a few days.

- **Clouds**
  - Clouds are condensed water droplets or ice crystals suspended above the Earth's surface. Clouds offer visual evidence of current atmospheric conditions and also indicate changing weather conditions.
  - Three basic types of clouds:
    - Cirrus - High clouds composed mostly of ice crystals. They are wispy or feathery in appearance.
    - Cumulus - Low to high puffy or head shaped clouds formed by rising turbulent air currents. Their presence indicates unstable conditions.
    - Stratus - Low-level layered clouds formed by the cooling of air below the saturation point.
  - Clouds are also categorized into families by altitude:
    - High - 20,000 ft and higher - mostly ice crystals.
    - Middle - 7,000 ft to 20,000. Water droplets or ice crystals depending on height.

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        - Low - Surface to 7,000 ft. Water droplets.
    - Prefixes/suffixes used in cloud designations:
        - Alto - Used to indicate middle (and occasionally high) clouds.
        - Nimbo/nimbus - Used to indicate rain producing clouds.
- Wind-Driven Current Systems
    - Wind causes the surface layer of the water to move. This surface motion is relayed to each successive layer below the surface. Friction causes the motion to dissipate with increasing depth.
    - Wind-driven currents do not flow in the direction of the wind due to the Coriolis force which is greater in high latitudes and deeper water. The deflection attributable to the Coriolis force is to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. The difference between wind direction and surface wind current varies between 15 and 45 degrees depending on water depth and geographic location. At greater depths (hundreds of fathoms) the current may flow in the opposite direction to the surface effect (this is known as the Elkman Spiral).
    - Major Current Systems:
        - Atlantic Ocean Currents
            - North Equatorial (starts northward of Cape Verde Islands and flows westward). Flows in vicinity of northeast trade winds.
            - South Equatorial (starts off the west coast of Africa and flows in westward direction). Flows in vicinity of southeast trades.
            - Gulf Stream (flows along the east coast of North America, around Florida, northward then northeastward to toward Cape Hatteras the curving eastward before slowing, broadening and becoming the North Atlantic Current.

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    - The North Atlantic ultimately divides into the Northeast Drift Current and the Southeast Drift Current.

- Pacific Ocean Currents
  - Pacific currents flow in the same general pattern as the Atlantic currents. The North Equatorial Current flows westward in the area of the northeast trade winds, and the South Equatorial Current flows westward in the vicinity of the southeast trades.
  - The Japan (Kuroshio) Current is similar to the Gulf Stream. It carries large quantities of warm water to higher latitudes. This current originates north of Taiwan and flows northeast past Japan, then moves in a more easterly direction. Eventually the current passes the Aleutian and Hawaiian islands and becomes the North Pacific Current.
- Indian Ocean Currents
  - The currents follow the general patterns of the Atlantic and Pacific Currents with some differences caused by the monsoons. During the Northern Hemisphere summer, the North Equatorial Current is replaced by the Monsoon current flows which flows eastward and southeastward across the Arabian Sea and Bay of Bengal.
  - The Agulhas Current originates at the southern end of Madagascar and flows southward then eastward. This current is analogous to the Gulf Stream.
- Sources of Environmental Predictions
  - Pilot charts provide, in color-coded graphic form, a complete forecast of the hydrographic, navigational, and meteorological conditions to be expected in a given ocean area in a given time of the year.
  - General Broadcast Messages
    - Oparea forecasts provide detailed 24 hr forecast with a 48 hr outlook for your operating area. Issued twice daily at 0000Z and 1200Z.

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- Tropical Warnings provide detailed warnings of tropical phenomena.
- Wind Warnings for extratropical storms
- High Sea Warnings for seas greater than 12 ft.
- Harbor Warnings
  - Small Craft Warnings are tailored to local conditions that are considered to be hazardous to boating and small craft.
  - Storm Surge Warnings are forecasts of the height and inland reach of abnormal tides resulting from storms in the area.
  - Local Severe Storm Warnings are forecasts of weather phenomena such as thunderstorms, squalls, tornadoes, hail, etc.

- Specific Address Broadcast Messages
  - WEAX (Individual route weather forecasts) provides a 24 hr weather synopsis tailored to a units specific operating area. WEAXs are requested in the ship's MOVREP.
  - OTSR (Optimum Track Shipping Route) recommends a track tailored to the needs, ship type, cargo, etc. of a requesting unit. OTSRs must be requested by message.

- **<u>Tropical Storms</u>**
  - Wind acts upon the ocean and alters its movements. Consequently, there is a strong relationship between the speed of the wind and the sea state in the area of the wind. The Beaufort scale is used to measure predicted winds which in turns enables the navigator to predict sea states. The scales ranges from 0 (calm) to 12 (hurricane).
  - <u>Cyclones</u> - A cyclone is a storm with strong winds rotating about a low pressure center. Cyclones rotate counterclockwise in the Northern Hemisphere, and clockwise in the Southern Hemisphere.

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- Extratropical Cyclones
  - Nontropical origin
  - Form along weather fronts (as discussed in pressure system section of this lecture).
  - Range in size from 500-2500 nm in diameter
  - Cold core
  - Rarely has an “eye” or calm defined center
  - Generally less intense than tropical storm
  - Most vigorous in winter months due to sharp conrast between polar and tropical air masses.
  - Moves East/Northeast in Northern Hemisphere
  - Classifications
    - Gale warning (34-47 kts)
    - Storm warning (48+ kts)
- Tropical Cyclones
  - Tropical origin
  - Range in size from 100-800 nm in diameter
  - Calm “eye” with calm winds and confused seas
  - Warm, moist core
  - Most active during summer/autumn months
  - More intense than extratropical cyclones
  - Moves West/Northwest in Northern Hemisphere
  - Classifications
    - Tropical depression (0-33 kts)
    - Tropical storm (34-63 kts)
    - Hurricane (64+ kts)

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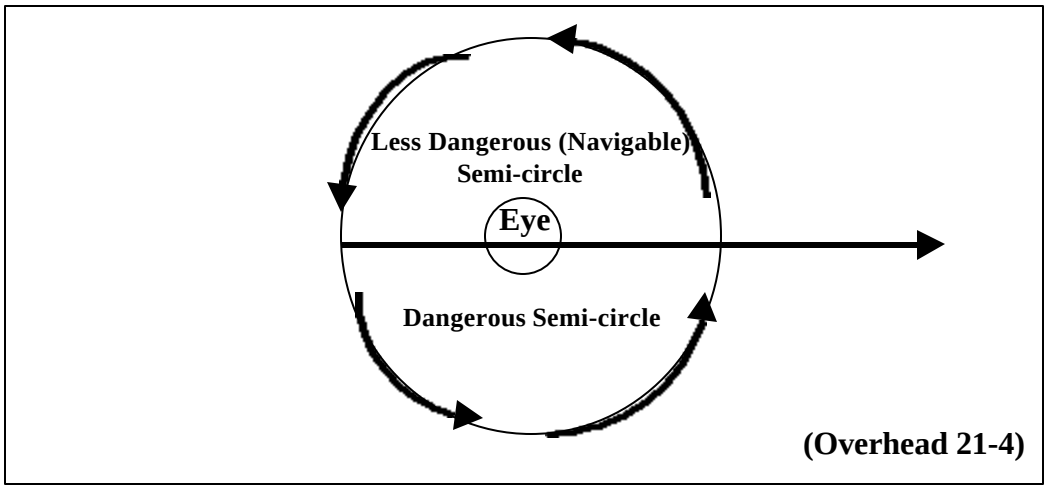
- Semicircles of a Hurricane
  - In the Northern Hemisphere, the semicircle to the right of the path of forward motion is known as the dangerous semicircle. The areas with the heaviest rain, strongest wind, and highest wind are located in this semicircle.
  - The semicircle to the left is the less dangerous semicircle



- Hurricane Evasion Techniques
  - Avoid if at all possible
  - Do not cross the forecasted path of the hurricane (this is known as crossing the "T")
  - In the Northern Hemisphere:
    - If you are caught in the dangerous semicircle, bring true wind onto the starboard bow (045R) and keep it there, while making as much headway as possible.
    - If you are caught in the navigable semi-circle, bring true wind onto the starboard quarter and keep it there, while making as much headway as possible.

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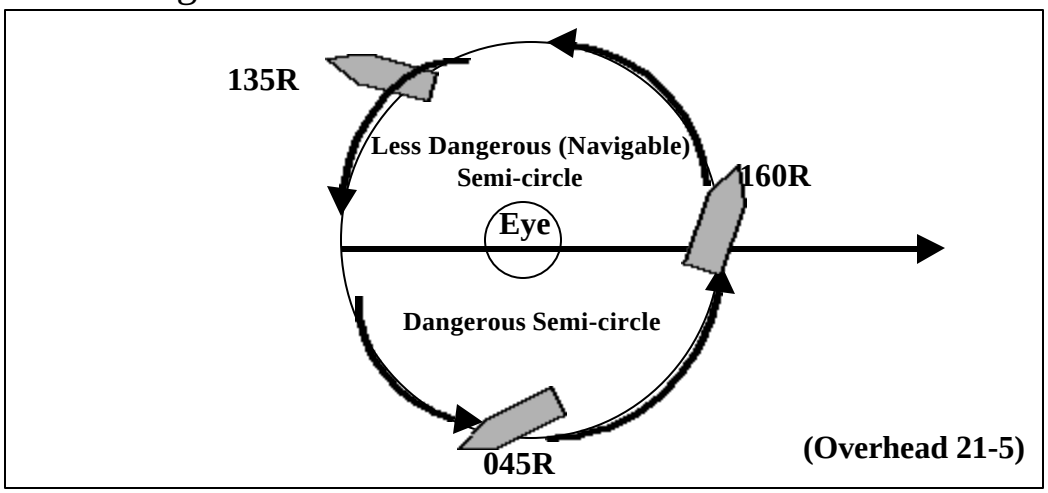
- If you are caught in the storm's path, bring true wind onto the starboard quarter (160R) and hold course until well within the navigable semicircle. Then maneuver as discussed above.



- **Ship's Heavy Weather Bill**
  - The SORM identifies the requirements for a ship's heavy weather bill.
  - The action taken during heavy weather will vary based upon location and severity of conditions. Some general actions are listed below:
    - Inport
      - Keep informed of current weather condition (Condition 4 = threat of destructive winds within 72 hrs, Condition 3 = Destructive winds possible within 48 hrs, Condition 2 = destructive winds are anticipated within 24 hrs, and Condition 1 = Destructive winds are anticipated within 12 hrs).
      - Station personnel to tend lines, fenders, and camels.
      - Keep CO, XO and CDO informed of preps for getting underway
      - Run additional mooring lines as necessary
      - Ensure topside equipment is strongly secured.

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- Underway
  - Keep CO informed of changes in atmospheric conditions.
  - Ensure personnel on watch are adequately protected.
  - Minimize number of personnel on wearer decks and ensure necessary personnel are wearing life jackets.
  - Ensure topside equipment is secured
  - Ensure all spaces inside the ship are secured for heavy weather
  - Increase rotation of watches.