**Learning Objectives by Topic for Physical Oceanography**
MSCI 301 – Coastal Carolina University

When we complete the **Properties of Seawater** section of the course, you should be able to:

1. Define salinity and be able to solve problems using the definition of salinity. Calculate salinity from chlorinity.
2. Define pressure and calculate the pressure of a fluid at depth.
3. Define temperature and potential temperature, and, using thermodynamics, explain why they are different. Draw graphs of T and Θ vs. depth. Draw and interpret graphs of temperature profiles for different latitudes. Define, identify and explain features of temperature profiles such as the mixed layer, thermocline, etc.
4. Use the Simple Equation of State to calculate pressure given S, T and depth, and vice versa. Explain how each variable affects the pressure. Explain why the equation is only an approximation. Define $\sigma$, $\sigma_t$ and $\sigma_\Theta$, explain how they are different and graph them vs. depth. Explain why density is important in determining the dynamics of water in the ocean.
5. Define stability and calculate it for two layers of water. Define the Brunt-Väisälä frequency and explain its use. Explain why stability is important in determining the dynamics of water in the ocean.

When we complete the **Waves** section of the course, you should be able to:

1. Identify the defining properties of a traveling wave, such as wavelength, amplitude, frequency, period, horizontal speed, vertical particle speed, and slope. Analyze the traveling wave formula and calculate these properties. Construct a traveling wave formula and draw a wave from information about a wave's properties.
2. Explain the forces that create oceanic gravity waves. Define wave energy and power. Explain how wind speed, duration and fetch affect the production of waves. Interpret spectral energy plots for information about the waves produced by different wind speeds in fully developed seas.
3. Describe the motion of water particles in surface waves and in internal waves. Describe the transfer of energy away from the surface or layer interface. Explain difference in particle orbits in deep water and shallow water.

4. Apply the oceanic wave speed equations to solve problems related to surface wave propagation. Explain where and why to use the deep-water and shallow-water approximations for this speed. Produce and interpret graphs of wave speed in computer spreadsheets.
5. Define and explain wave dispersion from a source. Define and explain superposition of traveling waves. Explain and calculate the group velocity of deep-water and shallow-water waves.
6. Explain the causes of and calculate the refraction angles of waves that move from one depth to another.
7. Define and explain the causes of tsunamis. Calculate the speed of these waves. Describe and explain their behavior as they come ashore.
8. Define and explain the causes of seiches in closed and open basins. Use the standing wave and wave speed equations to derive the relationship between a basin's length, depth and the period of forcing that will produce a standing wave. Apply this to explain real-world situations.

When we complete the **Tides** section of the course, you should be able to:

1. Illustrate and describe the relative motions of the earth, moon and sun. Define and illustrate such concepts as sidereal months, lunar months, sidereal days, lunar days and solar days.
2. Explain how the relative motion of the earth and moon and the gravitational force between the moon and the water on the earth combine to create the tidal bulges of the equilibrium tidal theory.
3. Use the equilibrium tidal theory to explain the length of the principal lunar tide and the principal solar tides. Illustrate and explain the relative positions of the earth, moon and sun that produce spring and neap tides. Illustrate and explain how this is caused by the superposition of waves.
4. Explain how the moon's declination affects the heights of the semi-diurnal tides.
5. List and explain the limitations of the equilibrium tidal theory.
6. Illustrate and explain an amphidromic system in a bay and extend to the ocean basins. Define amphidromic point, co-tidal lines and co-range lines.
7. Explain how tidal constituents are determined from long-term tidal records. Identify types of tidal curves such as semi-diurnal, diurnal and mixed. Determine the type of tide from the amplitude of the major constitents.

8. Acquire and download and graph predicted and actual water level data from NOAA archives. Explain deviations between these two sets of data.

When we complete the **Global Heat Fluxes** section of the course, you should be able to:

1. Define and explain terms such as heat flux, power, absorption, albedo, solar insolation, back radiation, latent heat flux, sensible heat flux, and advective heat flux.
2. Calculate the solar constant for the earth or any other planet. Explain the relationship between the radiation's incident angle and the amount of power hitting a certain latitude, calculate this number for any latitude and planetary tilt. Explain from this why the earth has seasons.
3. Explain the transfer of heat between different latitude belts and why this is important to the global climate system.
4. Calculate the incoming radiation incident on a certain location given information about the atmospheric absorption and albedo. Explain and illustrate how this fluctuates over a day, season or year. Determine the total energy flux into a location given numerical or graphical information about the solar insolation.
5. Calculate the outgoing longwave radiation (back radiation) given the temperature of a parcel of water. Determine the effective back radiation given information about the atmospheric absorption and reflection.
6. Calculate the heat lost through latent heat flux given information about the evaporation in a certain location. Calculate the heat gained or lost through sensible heat flux. Explain and use Bowen's ratio to relate the two.
7. Calculate the advective heat flux and or the total heat flux given information about the other parameters. Explain and illustrate the movement of heat into and out of basins. Calculate the increase or decrease in temperature of a parcel of water due to the combined heat fluxes. Relate this to global climate change.

When we complete the **Remote Sensing** section of the course, you should be able to:

1. Explain Lagrangian, Eulerian and synoptic approaches to ocean circulation. Discuss the advantages and disadvantages of each approach. Give examples of types of instruments used in each approach.

2. Describe the two types of satellites and three types of instruments used in satellite oceanography. Describe the advantages and disadvantages of each satellite type. Give examples of the ocean products derived from each satellite type.
3. Analyze SST and Ocean color images to form hypotheses on the ocean processes that are causing patterns in the images.

When we complete the **Thermohaline Circulation** section of the course, you should be able to:

1. Describe where and how deep and bottom waters are formed. Describe how surface heat fluxes play a vital role in deep water formation. Define caballing and describe why it is important in deep water formation.
2. Describe the formation, movement and extent of intermediate water masses.
3. Describe the temperature and salinity of major global water masses. Identify the water masses and determine their location of a given a T-S diagram. Draw a representative T-S diagram for any given ocean basin.
4. Describe the possible reasons that have previously led to, or might lead to in the future, the shutdown of NADW formation. Describe the consequences to Earth's climate to a shutdown.

When we complete the **ENSO/NAO** section of the course, you should be able to:

1. Describe the 3 phases of ENSO. List all the atmospheric and oceanic properties that are affected by the ENSO cycle.
2. Describe the methods and instruments used to observe ENSO.
3. Describe the 2 phases of NAO and the effects on climate that each phase has.

When we complete the **Hurricanes** section of the course, you should be able to:

1. Formation - Understand where hurricanes form and why this is. Understand the physical processes occurring during each of the four stages of hurricane formation.
2. Structure – Understand the internal structure of a hurricane and the physical processes that take place to strengthen the hurricane.
3. Steering currents - What are the steering currents for hurricanes and how do they change the path of a hurricane?

4. Understand how the path and forward speed of a hurricane will determine the extent of damage on land during and after landfall.
5. Know the three factors that cause the most damage when hurricanes make landfall.
6. Know the trends of hurricane activity during El Nino, La Nina, and non-El Nino periods and the processes that cause the observed trends.

When we complete the **Equations of Motion** section of the course, you should be able to:

*Continuity:*

1. Define and explain the concept of conservation of mass (continuity). Calculate the spatial derivative of velocity for 1, 2 and 3 dimensions, and explain the results.
2. Calculate flow rate, both mass per time and volume per time. Use conservation of mass considerations to solve for unknown flows.
3. Use the continuity equation with real-world data to determine unknown currents in the ocean.

*Equations of Motion:*

1. Draw and utilize the standard Oceanographic coordinate system.
2. Define, calculate and draw the Coriolis force, the pressure gradient, the pressure gradient force, gravity, viscosity, wind stress, Rossby number, etc.
3. Derive the Equations of motion in the x, y and z directions, starting from Newton's $2^{nd}$ Law. Explain each term in plain English.
4. Define, explain and calculate inertial currents.

*Geostrophic Balance:*

1. From the x and y equations of motion, derive the geostrophic balance. Explain all the assumptions that you make in order to arrive at it.
2. Qualitatively explain the meaning of the geostrophic balance.
3. Calculate the geostrophic velocities from information about sea surface height variations or density variations.
4. Interpret graphical representations of sea surface height

5. Interpret maps or graphs of atmospheric pressure or sea surface height variations and determine flow velocities. Draw maps of atmospheric pressure or sea surface height based on given observations. Explain how satellite measurements of sea surface height can be used to determine surface velocities.

*Ekman Balance:*

1. Define and explain molecular viscosity and eddy viscosity.
2. From the x and y equations of motion, derive the Ekman balance. Explain all the assumptions that you make in order to arrive at it.
3. Qualitatively explain the meaning of the Ekman balance.
4. Calculate and explain the direction of the surface current velocity.
5. Draw and explain the Ekman spiral, starting with wind friction and viscosity. Explain mass transport. Calculate the mass transport for a give wind field.
6. Draw and explain the mechanisms behind wind-induced upwelling and downwelling, including that in coastal areas, under hurricanes, and in other areas of the ocean with wind-induced convergence and divergence.
7. Calculate the vertical velocity at the bottom of the mixed layer from knowledge of the overlying wind velocities.

*Vorticity:*

1. Define and explain the curl of the velocity field. Define and explain planetary and relative vorticities for a variety of flow patterns, including circular flows and shear.
2. Calculate planetary and relative vorticities for given flow patterns.
3. Calculate absolute and potential vorticity. Using the concept of conservation of vorticity, explain how the flow or rotation of a parcel of water would change given changing conditions such as change in latitude or depth.

*Basin Circulation:*

1. Explain the general circulation patterns and westward intensification of the surface circulation of the sub-tropical basins using the following concepts:
    - Solar insolation
    - Latitudinal Wind Belts
    - Ekman transport
    - Geostrophic currents

- Continuity
- Conservation of Vorticity

2. Determine the change in circulation patterns given variations in these parameters.

When we complete the **Planetary Waves** section of the course, you should be able to:

1. Define Kelvin waves. Explain the balance of forces that allow them to propagate along coastlines or the equator. Draw the propagation of a Kelvin wave around a basin.
2. Define Rossby waves. Explain the necessary conditions for their existence, and how their motion is determined by conservation of vorticity. Give examples of common types of these waves.

When we complete the **Estuaries and Continental Shelf** section of the course, you should be able to:

1. State the classical and revised versions of the definition of an estuary. Explain why estuaries are important to humans and our environment.
2. List and describe the types of estuaries based on geomorphology.
3. Dynamics:
    - List the types of estuaries based on flow dynamics (stratified, partially mixed and well-mixed).
    - Describe the flow patterns and magnitudes in each.
    - Explain the physical causes of the flow patterns in each.
    - Draw and interpret figures of estuarine stratification and flows, including isohaline plots, vertical salinity profiles and layer flow patterns.
4. Explain the theory of conservation of mass and salt in an estuary. Apply the conservation equations and flow rate analysis to real-world problems. Predict what changes an estuary would occur with changes in parameters such as river flow rate, precipitation, etc.
5. Draw and describe the geography and characteristics of the inner, middle and outer shelf. Describe exchanges between the shelf and the rivers and estuaries of the coast.

6. Explain the effects of the Gulf Stream on the waters of the continental shelf, including upwelling and nutrient influxes.