Assessment Schedule – 2015

Earth and Space Science: Demonstrate understanding of processes in the ocean system (91413)

Evidence Statement

Q	Evidence	Achievement	Merit	Excellence
ONE	Near the Equator, water is warmed by the sun. The sun is more directly overhead in this area, so it warms the air and ocean more than the oblique sunlight of higher latitudes. This decreases the density of water so it expands, creating a bulge or hill of warm water, which flows down the sides of the hill due to gravity. The continents direct this surface flow north, transporting heat into higher latitudes. Nearer the North and South Poles, the water cools as the temperature is low due to indirect sun and much sun being reflected by ice. Cooler water has a higher density, causing it to sink. Evaporation at the Equator increases the salinity of the water, so the water flowing north is salty as well as warm. At the poles, as seawater freezes, it becomes more salty, as only fresh water is locked in the ice, concentrating the salinity of liquid water. Saltier water is more dense / heavier so sinks into the deep ocean, giving a salinity gradient. The combination of this downwelling pulling water into the deep ocean and pulling the warm water up from warmer regions to replace it drives this part of the ocean conveyor. The deep ocean water moves down towards Antarctica, where it is recharged by cold water sinking and pushed back northwards, upwelling in warmer coastal areas in the Indian and Pacific oceans as it is drawn up to replace heated surface water moving. This creates a global loop, continually mixing and turning over the ocean waters by gradients in density caused by salinity and temperature. Heat is transferred from hot, equatorial regions to regions that receive little sunlight, improving global climate as this heat is distributed to the atmosphere in cooler regions.	• Describes effect of direct sun on warming of water. • Describes that density decreases with warming / increases with cooling. • Describes how evaporation increases salinity. • Defines upwelling or down-welling. • Describes that freezing water increases salinity. • Links increasing salinity to increased density of water.	• Explains why the equatorial waters are heated more than polar regions (ie sunlight angle and / or ice albedo effect). • Explains TWO factors that affect salinity, e.g. evaporation, freezing, melting ice, precipitation. • Explains how temperature and / or salinity causes density of water to change in terms of particles.	• Discussion explains how a global circulation is achieved via temperature and salinity gradients causing upwelling and down-welling with reference to ‘bulge’ or gravity.

Not Achieved			Achievement		Merit		Excellence	
NØ = no response; no relevant evidence.	N1 = 1 point from Achievement.	N2 = 2 partial points from Achievement.	A3 = 2 points from Achievement.	A4 = 3 points from Achievement.	M5 = 1 point from Merit.	M6 = 2 points from Merit.	E7 = Excellence point with minor omissions.	E8 = Excellence point fully explained.

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TWO	Surface ocean currents are largely driven by wind. The '**normal**' condition has strong SE Trade winds pulling water due to friction away from the South American coastline. The thermocline is quite deep due to the mass of warm, less dense water above, i.e. the mixed layer. This layer is mixed by wind and waves. The thermocline acts as a barrier between the top mixed layer and the deep cold water, which is more dense. The thermocline has a rapid increase in density due to decrease in temperature. As water is pulled away from the eastern coast, it draws up deep cold water, carrying recycled nutrients from the deep. Because the thermocline is deeper in the west, this helps to drag up water from below it in the east. In **El Niño**, the trade winds weaken as the main heating and evaporation shift to the east. The upwelling at the eastern coast is lessened as the pull from the wind is decreased and the thermocline has flattened due to a smaller difference in temperature between the west and east Pacific. This causes upwelling (weak) from higher in the water column, where less nutrients exist, i.e. the deep, cold water is not brought to the surface. The nutrient load of the deep ocean water is due to sinking detritus from sea organisms and dissolved minerals carried down by density gradients. These nutrients would be trapped if not for upwelling regions, e.g. the Peruvian coast, bringing nutrients to the surface layer. With less of this deep water upwelling during El Niño, the sea is warmer and the fishing is poor along the coast with less nutrients for phytoplankton growth to feed the food web.	• Links ocean surface currents with wind. • States that warming in the western Pacific drives the trade winds. • Defines the three ocean layers. • Describes how thermocline acts as a barrier between the other two layers. • Describes upwelling process as bringing nutrients to the surface.	• Explains how upwelling brings nutrients to surface in terms of the thermocline. • Explains why the thermocline is deeper in the Western Pacific (Normal). • Links warmer waters in east in El Niño to deeper thermocline.	• Full explanation of why nutrients are reduced in El Niño conditions in the eastern Pacific. • Compares fully the effects of normal vs El Niño conditions on ocean layers and currents.

Not Achieved			Achievement		Merit		Excellence	
NØ = no response; no relevant evidence.	N1 = 1 point or 2 partial points from Achievement.	N2 = 2 partial points from Achievement.	A3 = 2 points from Achievement.	A4 = 3 points from Achievement.	M5 = 1 point from Merit.	M6 = 2 points from Merit.	E7 = 1 point from Excellence.	E8 = 2 points from Excellence.

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THREE	The **physical** / solubility pump is driven by the fact that carbon dioxide solubility is greater in cooler water (as the water particles have less kinetic energy so can maintain weak bonds with the gas). Carbon dioxide from the atmosphere dissolves in surface seawater. As water cools and sinks, (pressure also increases CO_2 solubility) more CO_2 dissolves, increasing concentration of dissolved inorganic carbon. This acts to pump carbon from the atmosphere into the ocean's depths. This dissolved CO_2 then undergoes further equilibrium reactions to hydrogen carbonate and carbonate, allowing more CO_2 to dissolve from the atmosphere. Conversion to carbonic acid: $CO_2 + H_2O \rightleftharpoons H_2CO_3$ $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ (hydrogen carbonate ion) $HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$ (carbonate ion) When deep water upwells in warmer, equatorial latitudes, it strongly outgasses carbon dioxide to the atmosphere because of the reduced solubility of the gas, but the carbon can be stored for centuries in the deep ocean. The **biological** carbon pump starts as phytoplankton use dissolved CO_2 to photosynthesise, storing carbon in their bodies and through the food web. Some plankton and other animals use CO_3^{2-} and HCO_3^- ions to build $CaCO_3$ shells, and these and other nutrient wastes sink to the ocean depths to be stored until recycled via upwelling of the thermohaline circulation. Some is stored longer term as limestone also. Higher temperature causes less CO_2 to dissolve in water so, in theory less is available for phytoplankton and less will be stored. However, as global warming is associated with higher CO_2, the opposite could occur – i.e. more carbon in the sea becoming carbonic acid, causing weakening of the shells of sea animals as carbonate reacts with acid. The buffering effect has kept pH stable, but as CO_2 levels rise, acidification is likely.	• Describes effect of temperature on CO_2 solubility/dissolving (NOT absorption). • Links depth to decreasing temp and increasing CO_2 storage. • Describes a carbon reaction in seawater. • Describes how marine organisms use or store carbon. • Links higher temperature to higher atmospheric CO_2 or ocean acidification. • Describes the role of upwelling / thermohaline circulation (THC) in cycling of carbon.	• Links reaction of aqueous CO_2 to various ions and ability to dissolve more atmospheric carbon. • Explains the biological carbon pump. • Links the physical and biological pumps to storage of carbon in the deep ocean.	• Discussion links the effects of temperature on the oceans' ability to store carbon via both physical and biological systems. • Explains why global warming is not affecting oceans as quickly as once thought likely – i.e. effect of buffering and / or competing issues of higher temperature and higher CO_2 on ocean systems.

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Cut Scores

Not Achieved	Achievement	Achievement with Merit	Achievement with Excellence
0 – 7	8 – 13	14 – 18	19 – 24