※ 注意：請於試卷內之「非選擇題作答區」依序作答，並應註明作答之大題及小題題號。

一、選擇題(30%)

The recent, apparently successful prediction by mathematical models of an appearance of El Nino-the warm ocean current that periodically develops along the Pacific coast of South America has excited researchers. Jacob Bjerknes pointed out over 20 years ago how winds might create either abnormally warm or abnormally cold water in the eastern equatorial Pacific. Nonetheless, until the development of – the models no one could explain why conditions should regularly shift from one to the other, as happens in the periodic oscillations between appearances of the warm El Nino and the cold so-called anti-El Nino. The answer, at least if the current model that links the behavior of the ocean to that of the atmosphere is correct, is to be found in the ocean.

It has long been known that during an El Nino, two conditions exist: (1) unusually warm water extends along the eastern Pacific, principally along the coasts of Ecuador and Peru, and (2) winds blow from the west into the warmer air rising over the warm water in the east. These winds tend to create a feedback mechanism by driving the warmer surface water into a "pile" that blocks the normal upwelling of deeper, cold water in the east and further warms the eastern water, thus strengthening- the wind still more. The contribution of the model is to show that the winds of an El Nino, which raise sea level in the east, simultaneously send a signal to the west lowering sea level. According to the model, that signal is generated as a negative Rossby wave, a wave of depressed, or negative, sea level, that moves westward parallel to the equator at 25 to 85 kilometers per day. Taking months to traverse the Pacific, Rossby waves march to the western boundary of the Pacific basin, which is modeled as a smooth wall but in reality consists of quite irregular island chains, such as, the Philippines and Indonesia.

When the waves meet the western boundary, they are reflected, and the model predicts that Rossby waves will be broken into numerous coastal Kelvin waves carrying the same negative sea-level signal. These eventually shoot toward the equator, and then head east- ward along the equator propelled by the rotation of the Earth at a speed of about 250 kilometers per day. When enough Kelvin waves of sufficient amplitude arrive from the western Pacific, their negative sea-level signal overcomes the feedback mechanism tending to raise the sea level, and they begin to drive the system into the opposite cold mode. This produces a gradual shift in winds, one that will eventually send positive sea-level Rossby waves westward, waves that will eventually return as cold cycle-ending Positive Kelvin waves, beginning another warming cycle. [credit: GRE subject]

1.1. The primary function of the passage as a whole is to(5%)
(A) introduce a new explanation of a physical phenomenon
(B) explain the difference between two related physical phenomena
(C) illustrate the limitations of applying mathematics to complicated physical phenomena
(D) indicate the direction that research into a particular physical phenomenon should take
(E) clarify the differences between an old explanation of a physical phenomenon and a new model of it

1.2. According to the passage, which of the following features is characteristic of an El Nino? (5%)
(A) Cold coastal water near Peru
(B) Winds blowing from the west
(C) Random occurrence .
(D) Worldwide effects
(E) Short duration

1.3. According to the model presented in the passage, which of the following normally signals the disappearance of an El Nino? (5%)
(A) The arrival in the eastern Pacific of negative sea-level Kelvin waves.
(B) A shift in the direction of the winds produced by the start of an anti-El Nino elsewhere in the Pacific.
(C) The reflection of Kelvin waves after they reach the eastern boundary of the Pacific, along Ecuador and Peru.
(D) An increase in the speed at which negative Rossby waves cross the Pacific.
(E) The creation of a reservoir of colder, deep ocean water trapped under the pile of warmer, surface ocean water.

1.4. It can be inferred from the passage that which of the following would result fairly immediately from the cessation of the winds of an El Nino? (5%)
I. Negative Rossby waves would cease to be generated in the eastern Pacific.
II. The sea level in the eastern Pacific would fall.
III. The surface water in the eastern Pacific would again be cooled by being mixed with deep water.
(A) I only
(B) II only
(C) I and II only
(D) I and III only
(E) I, II, and III

1.5. The passage best supports the conclusion that during an anti-El Nino the fastest-moving signal waves are (5%)
(A) negative Rossby waves moving east along the equator
(B) positive Rossby waves moving west along the equator
(C) negative Kelvin waves moving west along the equator
(D) positive Kelvin waves moving west along the equator
(E) positive Kelvin waves moving east along the equator

1.6. What does the underlined word "waves" in Paragraph 3 refer to? (5%)
(A) Kelvin waves
(B) Sea-level signals
(C) Coastal waves
(D) Rossby waves

二、敘述大意(70%)

2.1. The trenches and ridges on Earth's seafloor are shaped by tectonic processes such as seafloor spreading and plate subduction. Detailed knowledge of seafloor tectonics is lacking in many areas. The most comprehensive data come from satellite altimeters, which use the strength and waveform of the radar signal returned from the sea surface to determine the tectonic properties of the underlying seafloor. The 1- to 2-mGal gravity accuracies achieved by Sandwell et al. (Science, 2014) are based on worldwide comparisons between altimeter gravity and high-quality ship gravity at wavelengths between 12 and 40 km. A gravity measurement accuracy of 1 mGal requires 1-mm accuracy in SSH (sea surface height) measurements over 1 km along satellite ground tracks. This accuracy is a very challenging goal for measurement technology and data processing alike, especially in coastal areas and large inland water bodies such as the Caspian Sea, the Black Sea, and the Great Lakes. (10%)
(節錄自 Hwang and Chang, Science, 2014, vol 346, pages 32-33)

接次頁

2.2. Great earthquakes are those whose moment magnitudes are 8.0 or higher. Their activity varies significantly between different subduction zones. Some subduction zones—for example, ones in southern Chile, Sumatra, and southwestern Japan—produce repeated, great-earthquake ruptures every century or two, while others—in the Mariana Islands and Tonga, say—produce them rarely, if ever. The variability is attributable to differences in plate-boundary frictional characteristics. At shallow depths, it can rupture as tsunami earthquakes—a name reserved for large, tsunami-generating events that, because of unusually low rupture- expansion rates, occur without generating strong, short-period seismic waves. Conditionally stable regions normally slip continuously but can also slip seismically when loaded abruptly during the failure of neighboring fault planes. (10%)
(節錄自 Lay and Kanamori, Physics Today, 2011, 64(12), 33 (2011); doi: 10.1063/PT.3.1361)

2.3. We understand why Earth's mantle convects: there is no alternative mechanism for eliminating heat. However, we do not understand why Earth has plate tectonics. It is sometimes described as merely a property of the particular form that mantle convection takes on our planet, but this begs the question. Plate tectonics is neither mandatory nor common (there is no clear evidence of its existence on any other planet so far). Nonetheless, many think its presence is deterministic: given the specific parameters of present-day Earth, it is the behaviour expected, in the same sense that a physicist setting up a convection experiment on a layer of fluid heated from below need not be concerned about whether his chosen fluid was once a vapour or a solid. Even in this point of view, the presence of plate tectonics is history-dependent. (10%)
(節錄自 Stevenson, Nature, 2008, 45(17), doi:10.1038)

2.4. Continental margins for regulating the increasing of atmospheric CO2 have been recognized as a high priority to examine the distinctive processes and important interfacial exchanges during the Anthropocene Era (e.g., Tsunogai et al., 1999; Thomas, 2004, Bauer et al., 2013). Continental margins generally receive large loads of carbon from land on the one hand and sustain rapid biological growth and biogeochemical cycling with rates much higher than those in the open ocean, on the other hand (Walsh, 1991). They, despite only having 8% of the whole ocean area, overall play a significant role in the global biogeochemical cycle as a net sink of atmospheric CO2 (0.2~0.5 Gt C y^{-1}), which is ca. 10%~30% of the current estimate of global oceanic CO2 uptake (Borges et al., 2005; Cai et al., 2006; Chen and Borges, 2009; Laruelle, et al., 2010). The disproportionate findings have recently drawn more attentions to the role of continental margins in the global carbon cycle. Additionally, the coastal seawaters interact and exchange strongly in complex ways with the atmosphere, and the open ocean. The environment complexities and diversity of the marginal seas thus pose a challenge to characterization of the dynamic carbon cycling in these regions. The abovementioned estimates still existed with large uncertainties. Most importantly, that's because many shelf regions were grossly undersampled, especially the mid-latitude continental shelves (Borge et al., 2010). (8%)

2.5. Globally, the marginal seas act as a source or sink for CO2 depending on the geographic differences with environmental settings. There is generally a sink for atmospheric CO2 at mid- and high-latitudes, while a source of CO2 at low latitudes (between 30°S - 30°N) such as the South China Sea (SCS). The East China Sea (ECS) is situated between the low- and mid-latitudes (between 25°N-34°N) with estimated overall CO2 sink strength of 1~3 mol C m-2 yr-1 (Peng, et al., 1999; Tsunogai et al., 1999; Wang et al., 2000; Shim et al., 2007; Zhai and Dai, 2009; Tseng et al., 2011, 2014). The relatively high uptake capacity for absorbing atmospheric CO2 is 0.01~0.03 Gt C annually (0.5~2.0% of the global uptake in ~0.2% of global ocean area), compared to other ocean regions. The ECS hence represents as a pivotally typical shelf system for efficient drawdown and transfer of atmospheric CO2, which is so-called "continental shelf pump" (Tsunogai et al., 1999). The main mechanisms include active biological uptake of CO2 in the warm periods (e.g. late spring, summer), high CO2 solubility in the winter, and then effective shelf transport and shelf-edge export processes of particulate and dissolved carbon species to the deep ocean. (8%)

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2.6. Tseng et al. (2011, 2014) demonstrated evidence of strong control of Changjiang river discharge (CRD) on the CO2 uptake capacity of the ECS. They found biological sequestration of CO2 taking place in the highly productive Changjiang river plume in warm seasons. The Changjiang (a.k.a Yangtze River, the world's fourth largest river by water discharge) bring huge amounts of nutrients (e.g., N, Si etc.) to the ECS shelf, which is responsible for the flourishing phytoplankton in the plume area [Gong et al., 2003]. A strong sink of atmospheric CO2 by biological uptake in spring and summer contributes ~60% of an annual total sink (1.8±0.5 mol C m^{-2} y^{-1}, Tseng et al., 2014). However, the uptake capacity of atmospheric CO2 in the ECS is susceptible to disruption during environmental changes. The river discharge of Changjiang, on the one hand, is being altered due to operation of the Three Gorges Dam (TGD) and over fifty thousand smaller reservoirs and other human-modulated water-transfer schemes (http://www.threegorgesprobe.org/tgp). On the other hand, elevated nutrient discharge causes eutrophication and hypoxia of coastal waters in the ECS. Consequently, the alteration of the river runoffs from Changjiang due to climate oscillation and human perturbations would eventually cause changes in the CO2 uptake capacity in the ECS shelf. (8%)

2.7. Moreover, Tseng et al. (2014) affirmed previously published air-sea CO2 fluxes in the ECS were biased by inadequate spatial and/or temporal coverage. Tsunogai et al. (1999) first, for instance, showed estimates of ~3 mol C m^{-2} y^{r-1} uptake of the ECS from atmospheric CO2 based on extrapolating from a single transect data of the PN (Pollution Nagasaki) line across the central ECS. Other later CO2 flux studies in the ECS with uptake rates of 1~ 3 mol C m^{-2} y^{r-1} had been spatially limited as well. Peng et al (1999) and Wang et al. (2000) mostly studied at the middle and outer shelves in one or two seasons with low-resolution samplings. Shim et al. (2007) had limited spatial surveys in the northeastern ECS. Moreover, a reliable and complete quantification in seasonally representative CO2 uptakes by the whole ECS was lacked in the past decades. Only a few available data have been reported for the seasonality of the air-sea CO2 fluxes in outer Changjiang Estuary mostly within inner shelf region (Zhai and Dai, 2009). The near-shore region, covering less 10% of the total ECS surface area, is a highly dynamic zone with strong biological activities e.g., high heterogeneous respiration. (8%)

2.8. Until recently, Tseng et al. (2011, 2014) provided better quantification of the ECS CO2 uptake in terms of greater spatial and temporal resolutions/coverage in a 14-year observational data. They performed more direct and reliable near surface underway pCO2 measurements on a basis of season in the ECS (25-32°N and 120-128°E). The representativeness of study area, in spite of covering an area about a half of the whole ECS, has been proved through the good calibration of satellite sea surface temperature (SST) with field data and relationship of Changjiang river discharge and plume area. They thus explored seasonally representative CO2 uptakes by the whole ECS derived from observations with model estimates, generated by an empirical algorithm as a function of SST and CRD. The resultant algorithm provided better quantification of shelf CO2 uptake capacity in the ECS. An annually averaged CO2 uptake from atmosphere was constrained to half of the upper value, 3 mol C m^{-2} y^{-1}. This assessment of annual CO2 uptake is largely improved relative to previous estimates. Additionally, distinct seasonal pattern and apparent inter-annual variations in air-sea exchange fluxes of CO2 were also revealed through the CO2 time-series in the ECS (Tseng et al. 2011, 2014). (8%)

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