Climate Changes: past, present, and future

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Since the release of the report by the Intergovernmental Panel on Climate Change in February 2007, there has been a lot of press coverage both in Hong Kong and in the world on the possible adverse effects of climate change in the coming decades. The fact that we had the hottest Lunar New Year's day on record (25.3 degrees Celsius) also heightened the local interest on this topic. Will the temperature get to unbearable levels? Will the rise in sea level resulting from the melting of polar ice destroy our habitat? Will Hong Kong be a livable place 50 years from now?

While there is almost indisputable evidence that human activities contribute to global warming, the predicted degree of temperature rise and the causes behind such rises remain uncertain. At a local level, the continuous rise in recorded temperatures has a variety of factors behind it, and to accurately assess the cause and corrective actions to take is not a trivial matter.

Our current appreciation of the importance of carbon dioxide (CO_2) on global temperatures began with the space probe to the planet Venus, where astronomers discovered that large amount of atmospheric concentration of CO_2 is responsible for Venus' high surface temperature (700 degrees Celsius). Like a greenhouse, CO_2 allows the sunlight to come in but blocks 99% of all infrared radiation emitted from the surface of Venus. This provides us with an important lesson: we can learn a lot about the Earth by observing other planets and satellites in the solar system.

The Earth is an integrated system consisting of its solid crust, oceans, and the very thin and fragile atmosphere. The increased amount of CO_2 in the atmosphere will warm the ocean, which can lead to increased frequency of calamities such as typhoons, and change the pattern of ocean currents that permit the high latitude European countries to have mild winters. The oceans also absorb much of the CO_2 in the atmosphere, and interactions between the atmosphere, oceans, and the solid crust can be very complicated. In order for us to have a full understanding of climate change, we need to study the physical, chemical, and biological processes at work in all these three components.

We also have to recognize and learn from the fact that our Earth has undergone drastic changes in climate over its history. Our current atmosphere is made up of nitrogen and oxygen molecules, with small amounts of argon, CO_2 and water vapor. However, that was not the way it was at the beginning. Our primordial atmosphere consisting of hydrogen, helium, methane, ammonia and water was totally lost through evaporation, and was replaced 4 billion years ago by a secondary atmosphere by gases released from the interior. The emergence of life and the onset of photosynthesis by microbes 3.5 billion years ago introduced oxygen to our

atmosphere, which has later become the essential element for animal life.

About 4 billion years ago, the impact of a Mar-sized object on Earth created the Moon, and bombardment by comets introduced steam which cooled to form (or at least contributed to the formation of) the oceans. In various times, impacts from extraterrestrial objects such as asteroids and comets created so much dust and debris that they shielded the Earth from sunlight, leading to significant cooling and causing mass extinctions of living species. The most well-known event was the impact near Yucatan Peninsula in Mexico 65 million years that killed off the dinosaurs. Our fluctuating climate was modulated by the recycling of CO_2 and water trapped in carbonates in the Earth's crust through movement of continents (plate tectonics) on timescales of tens of millions of years. On shorter time scales, the variations of the orbital and spin motions of the Earth have led to major episodes of glaciations and large changes in global temperatures.

There is no doubt that recent human activities have an impact on our environment. On a short period of only a hundred years, human beings have managed to have significantly altered our surroundings. The burning of fossil fuels has enhanced the greenhouse effect through the release of CO_2, and the injection of chemicals have led to ozone depletion in the stratosphere, resulting in increased exposure to solar ultraviolet radiation. Factory emissions have produced large amounts of acid precipitation which has undesirable effects on living things.

In summary, there has been significant climate change over the history of the Earth due to internal and external factors. These changes are accelerated in recent times by human activities. In order for us to make the correct economic and political responses to these changes, we need to have a comprehensive understanding of the forces at work. We need to study all components of the Earth, and to learn lessons from other planets (e.g., Venus and Mars) and satellites (e.g., Titan and Europa) in the solar system.

The fundamental element of good science is observations. We need to monitor our home planet by keeping track of the radiation flux of the Sun, changes in chemical composition of the atmosphere, changes in snow, ice, and cloud cover, changes in temperature on land, in the seas, and in the atmosphere, as well as changes of the biosphere. All these observations are now being undertaken from space, the only place one can have a global perspective.

An understanding of physics, chemistry, biology, ecology, geology, palaeontology, as well as astronomy is required to tackle these problems. Only with an interdisciplinary approach and using space-observations as a platform, can we correctly predict our future. The universities in Hong Kong can play a role in this worthwhile venture by building on our existing expertise and collaborate with each other. There is not a more pressing problem facing the world today.

A color mosaic of the Earth built up from 1561 orbits of observations by the Envisat satellite. The oceans, ice caps, vegetation, and deserts can easily be seen in this picture (credit: European Space Agency).