Prediction of climate modes for human security and sustainability

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Abstract:

It is not climate change but climate variation that is directly related to abnormal weather and extreme phenomena. The distiction between change and variation is important in developing mitigation and adaptation measures for human security and susutainability. After describing newly discovered climate modes, I stress the importance of promoting skills of seasonal prediction for early warning of droughts, floods, abnormally high and low temperatures, etc.. This is particularly so in developing countries that are vulnerable to those impacts. The prediction may be extended to indices related to agriculture and human health, thus contributing directly to human security and sustainability.

Key words: climate change, climate variability, climate modes, human security, sustainability

Climate change and climate variation

A Google search for the word "global warming" produces about eighty million entries. The more general word "climate change" hits even more above one hundred million entries. Not a day goes by without some mention of either global warming of climate change in the media. There are misunderstandings, however, at all levels in the information that floods our society. One of these misunderstandings is the tendency to confuse "climate change" with "climate variation". Climate variation refers to a situation in which, due to various internal factors, climate fluctuates significantly around the normal state from seasons to decades. A period of thirty years is often used to define the normal state by averaging. On the other hand, climate change refers to a situation in which this normal state changes over a much longer period of time. This results from some external origins such as the increase of greenhouse gases due to anthropogenic activities. The interplay between climate variation and climate change even enhanced the complication, as we observed in the hot debate of "global warming hiatus" (e.g. Kosaka and Xie 2013).

Severe flooding in Thailand in 2011 resulted in a total of 815 deaths and 13.6 million people affected. Economic losses estimated by the World Bank amounted to US$45.7 billion due to the inundated manufacturing industry and disruptions of manufacturing supply chains. Super typhoon Yolanda, one of the strongest tropical cyclones ever recorded, devastated the Philippines in November, 2013, killing at least 6,300 people. Those destructive extreme events are due to extreme cases among day-to-day meteorological phenomena called weather. When the weather differs significantly from normal years over the season as a whole, they could justifiably be called "climate variation". Concentrations of carbon dioxide, one of the "greenhouse gases", have been increasing since the industrial revolution; the relationship between this and the gradual rise in earth surface temperatures has become a major focal point as a problem of global warming. Since this is mostly caused by human activity outside the atmospheric and oceanic system, it is a problem of climate change. The earth's rotational orbit and the tilt of the earth's axis fluctuate on a timescale of tens of thousands of years or more. These cause ice ages and interglacial periods due to changes in the sunlight radiation shed on the earth, and as such, these may also be described as climate change.

Given this interpretation, it is somewhat embarrassing that, in Japanese, the IPCC is still translated as the "Intergovernmental Panel on Climate Variation" and the UNFCC as the "United Nations Framework Convention on Climate Variation". In fact, of course, they should have been translated literally as "Intergovernmental Panel on Climate Change" and "United Nations Framework Convention on Climate Change", as they are in English. Again, "global warming projection" is often translated in Japanese as "global warming prediction", but the word "prediction" invites misunderstanding that the climate change projection could be formulated as an initial value problem just like the manner of a weather forecast. Since this is a future projection with a high degree of uncertainty, depending partly on scenarios such as socio-economic policies, it should more correctly be translated as "global warming projection". In fact, IPCC reports make very careful distinctions between the terms "variation" and "change", "prediction" and "projection".

What I am anxious about here does not seem to be limited in Japan. The misunderstanding looks ubiquitous in the world nowadays. This distinction between the concepts of "variation" and "change" is by no means limited to the realm of semantics. It causes serious discrepancies when considering application measures for local communities. It is not climate change but climate variation that is directly related to the abnormal weather and extreme phenomena which impact our socio-economic conditions and thus influence human security and sustainability. Climate change is the change in the background state which may modulate climate variation.

New basin-wide climate modes causing climate variation

Tropical oceans play a major role in natural variability of the world climate. Anomalous coupled ocean-atmosphere phenomena generated in the tropical oceans produce changes in global atmospheric and oceanic circulation that influence regional climate conditions even in remote regions. On the interannual time-scale, the El Niño/Southern Oscillation (ENSO) of the tropical Pacific Ocean is known as a typical example of such phenomena (Fig. 23.1) and has received worldwide attention because of its enormous societal impact (Philander 1990). However, various ocean/atmosphere datasets in recent decades led us to discover the existence of a new basin-wide climate modes in the tropical Indo- Pacific Oceans. We here focus on the ENSO Modoki in the Pacific (Weng et al. 2007; Ashok et al. 2007; Ashok and Yamagata 2009) and the IOD in the Indian Ocean (Saji et al. 1999; Yamagata et al. 2004)

The unique central Pacific warming of this new mode is associated with a horseshoe sea surface temperature (SST) pattern, and is flanked by a colder anomaly on both sides along the equator. Such a zonal SST distribution results in anomalous two-cell Walker circulations over the tropical Pacific. Both the Intertropical Convergence Zone (ITCZ) and the South Pacific Convergence Zone (SPCZ) expand poleward, forming a wet region in the central tropical Pacific. Since the mode cannot be described as one phase of El Niño evolution, the phenomenon may be called El Niño Modoki (or Pseudo-El Niño). The El Niño Modoki involves ocean-atmosphere coupled processes, indicating the existence of a unique atmospheric component during the evolution, analogous to the Southern Oscillation in the case of El Niño (Fig. 23.2). The Modoki's impact on world climate is very different from that of ENSO. Possible geographical regions for droughts and floods influenced by Modoki and ENSO are compared. Interestingly, the Modoki's influences over regions such as the Far East including Japan and the western coast of USA are almost opposite to those of the conventional ENSO. The difference maps between the two periods 1979-2004 and 1958-1978 for various oceanic/atmospheric variables suggest that the recent weakening of equatorial easterlies related to a weakened zonal sea surface temperature gradient led to more flattening of the thermocline in the equatorial Pacific. This appears to be a cause of more frequent and persistent occurrence of the Modoki event during relatively recent warming decades.

In contrast to the Pacific, the interannual variability originating in the tropical Indian Ocean has received less attention for a long period because of the dominance of the Indian monsoon. However, it turned out that the anomalous event in 1994 was due to an ocean-atmosphere coupled phenomenon. This coupled mode is now widely called the Indian Ocean Dipole (IOD) on the basis of Saji et al. (1999). During the IOD event, an east-west zonal dipole pattern of sea surface temperature (SST) evolves in the tropical Indian Ocean. The SST pattern is associated with zonal surface wind anomalies. Changes in the surface winds are associated with surface pressure anomalies just as in the ENSO of the Pacific. The IOD has its unique teleconnection pattern that implies regional climate variability and thus societal impacts in various parts of the globe (Fig. 23.3). Since IOD and ENSO indices are not completely orthogonal, the IOD influences must be carefully appreciated for societal application purposes. Recent statistical and dynamical studies have clearly revealed that the enhancement of the East African short rains is due to IOD rather than El Nino, in contrast to the conventional view (Behera et al. 2005).

Importance of predicting climate modes and their impacts

Appreciating the differences among various climate modes and their impacts as discussed above not only enhances our understanding of coupled ocean-atmosphere dynamics but also contributes to improved prediction of seasonal climate variation that generates extreme as well as abnormal weather events in various parts of the world by their teleconnection. Simulation models needed to predict climate variation must resolve rich natural phenomena with different space and time scales. It is extremely important to understand the above graded structure. Let me give a specific example. A phenomenon called the Pacific-Japan pattern (PJ pattern) brings summer to Japan and East Asia. From around April, the sun reaches a high elevation near Indonesia, stimulating convection activity there. Warm air rises, and then falls near the Philippines. The resultant fine weather over waters near the Philippines causes seawater temperatures to rise significantly there. Then, in around July, the center of convection activity jumps to this warmed sea region. The region of falling warm air moves northwards in tandem, until the region near Japan is covered with the Bonin (Ogasawara) high, ushering in the summer. This is called the atmospheric PJ pattern by the late Professor T. Nitta of the University of Tokyo (Nitta and Yamada, 1989). El Niño is a phenomenon that interrupts this seasonal progression and causes cool summer in Japan. When this phenomenon occurs, the warm seawater near the Philippines moves towards the region ranging from the eastern Pacific to the International Date Line, making strong convection less likely to occur. The Bonin (Ogasawara) high that brings summer to Japan is not reinforced, either. On the other hand, it has become clear that, if positive Indian Ocean Dipole Mode occurs in the Indian Ocean, convection becomes active over the region ranging from northern India to near the Philippines. In that case, summer temperatures in Japan become extremely high. In 2016, negative Indian Ocean Dipole occurred and the active convection in the eastern tropical Indian Ocean introduced strong downdraft near the Philippines. This suppressed convection there. Also, the warm water pool was not enough because of the persisting influence of the super El Niño which occurred in 2015/16. Those are reasons why not many typhoons were generated in summer of 2016.

Though somewhat hidden behind more prominent IPCC topics for climate change, initiatives aimed at predicting climate variation, rather than projecting climate change, have been progressing rapidly of late in professional climate science community. We are now at the level whereby the occurrence of climate modes such as El Niño can be predicted several seasons or even one or two years in advance. This is all due to rapid growth in global earth observation using satellites and *in situ* instruments, the enhancement of scientific knowledge, and advances in techniques for assimilating observed data into models and making seasonal predictions.

Crossing the boundary between science and society

Predicting the likelihood of droughts, floods, abnormally high or low temperatures, etc., between several months and one year in advance will make a great contribution to socio-economic activities as well as well-being of human beings. The skill in seasonal prediction now covers indices more than physical ones. For example, the year-to-year variation of crops yields and climate-sensitive infectious diseases is now in the realm of seasonal prediction (e.g. Yuan and Yamagata 2015). One of the innovative aspects of predicting climate variation is in its role of removing the boundary between science and society for human security and sustainability (cf. Zebiak et al. 2014).

Measures aimed at protecting the global environment should be promoted in parallel with this prediction of climate variation and application measures based on it. Systems in developing countries are particularly vulnerable to flooding, drought, and other calamities. If we can cooperate, based on predicted data, in preventing or mitigating disasters as well as promoting infrastructure development and capacity building in this direction, we should be able to encourage people in developing countries to understand measures to cherish the rich asset of natural environment, as well.

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Figures:

Fig. 23.1 El Niño impacts in boreal summer (orange: warm air and sea surface temperature anomalies; blue: cold air and sea surface temperature anomalies; shading: anomalously dry region; cloud: anomalously wet region)

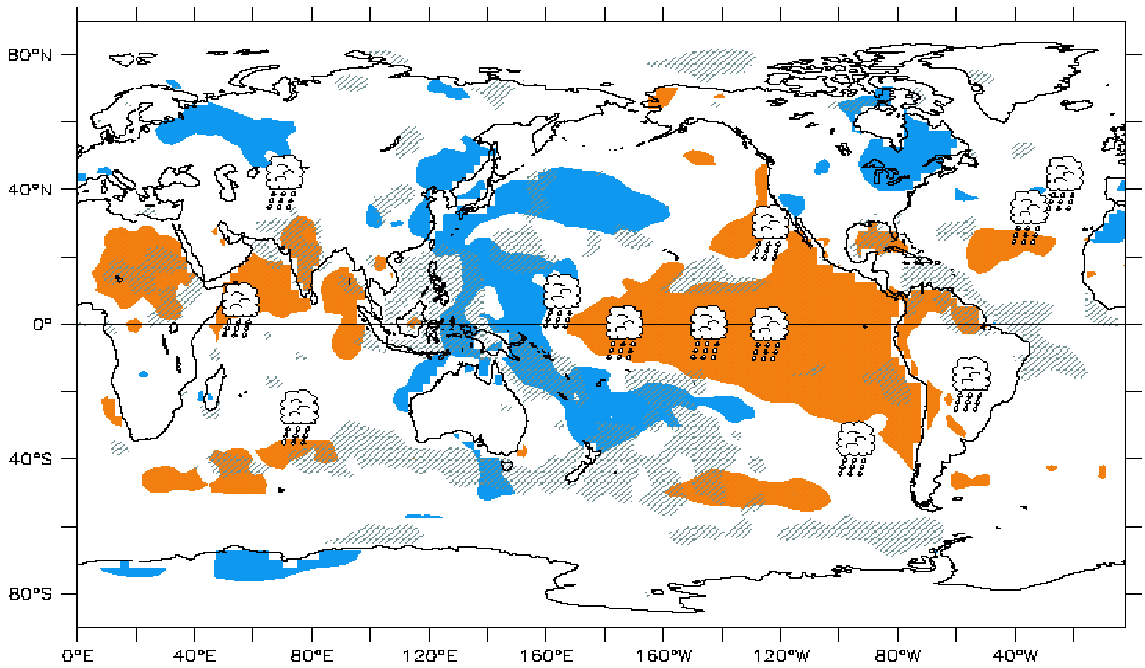


Fig. 23. 2 Schematic pictures for ENSO (El Niño and La Niña) and ENSO Modoki (El Niño Modoki and La Niña Modoki)

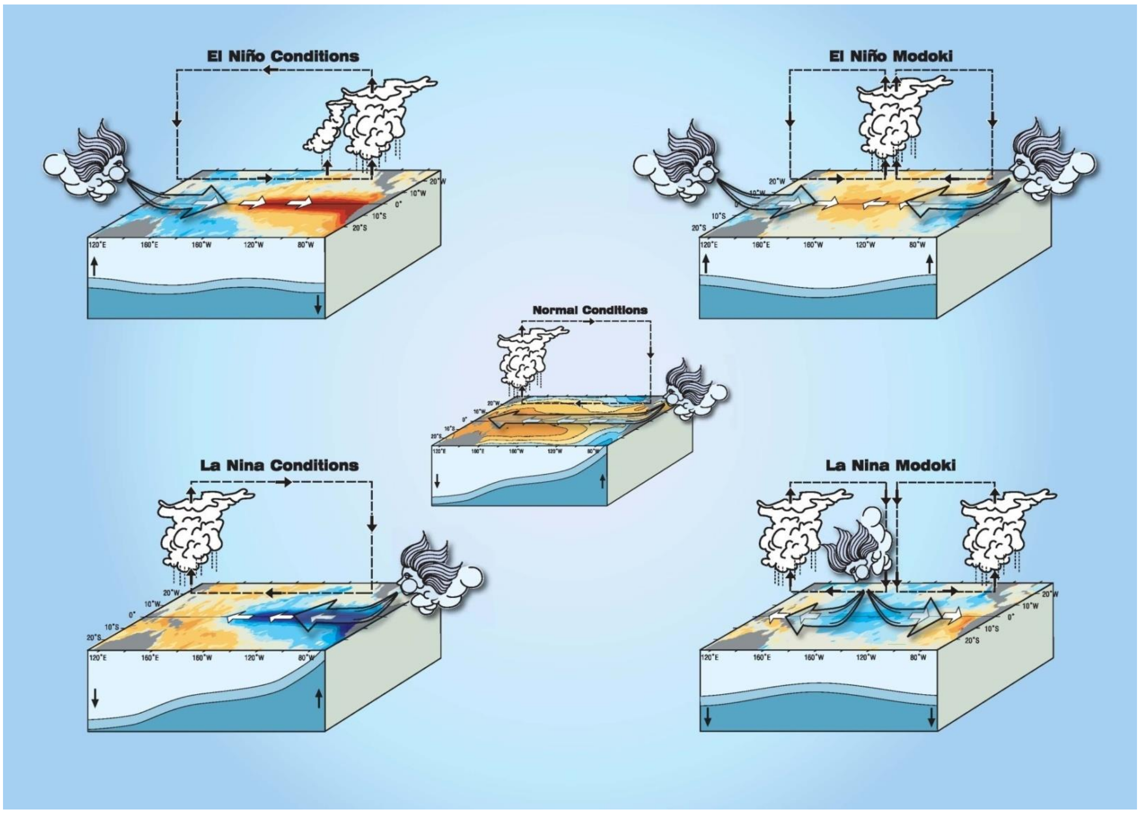
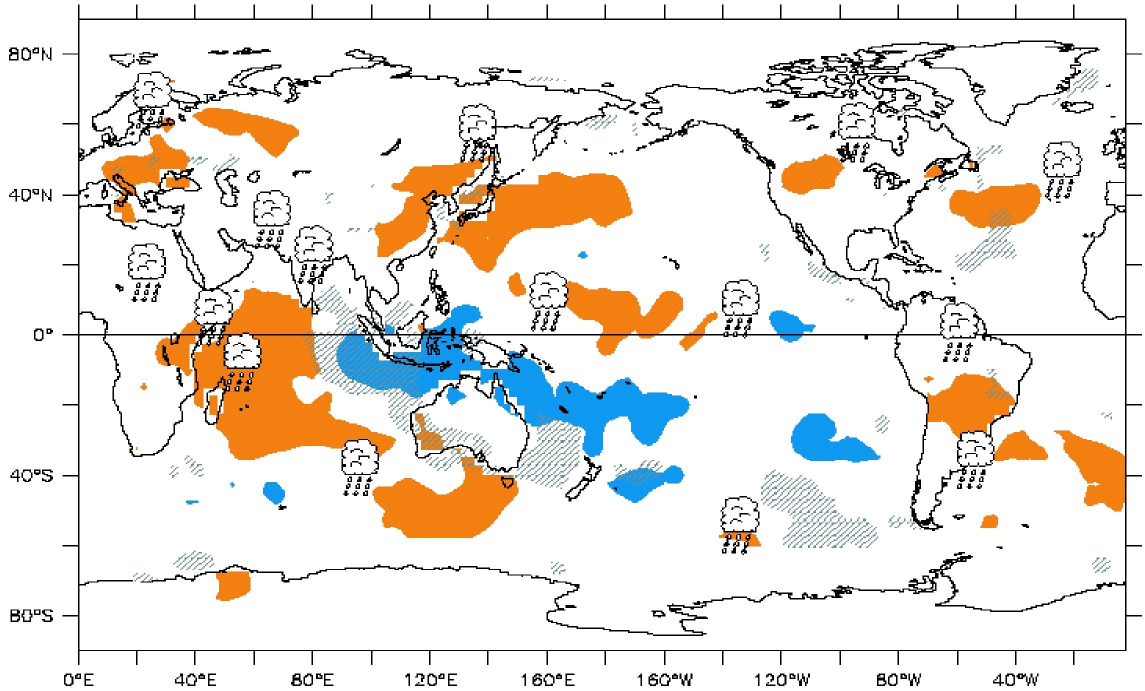


Fig. 23.3 Positive Indian Ocean Dipole Mode (IOD) impacts in boreal summer (orange: warm air and sea surface temperature anomalies; blue: cold air and sea surface temperature anomalies; shading: anomalously dry region; cloud: anomalously wet region)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