Is an El Niño on the way and what might its impacts be?

June 2014

Contents

EXECUTIVE SUMMARY

This year has seen changes taking place in the equatorial Pacific Ocean that have heralded the onset of an El Niño event, with the potential to cause major climatic impacts around the world. This report considers the current evidence for an El Niño event this year, discusses the potential strength of the event, and considers what its global impacts might be.

The current assessment presented in this report is that an El Niño is probable, but that its strength is likely to be moderate, similar to the 2009/10 event. The feedbacks between the atmosphere and ocean that act to amplify a developing El Niño have not been active so far in the Pacific basin, raising questions about its evolution over the coming months and its impacts on the global climate system.

This report also looks in more detail at the different flavours of El Niño and their global impacts, with the aim of providing more discriminatory evidence on possible impacts of this year's developing El Niño. In particular the report emphasises that the differing types of El Niño affect global mean surface temperatures differently, with only strong East Pacific El Niño events leading to a large global warming.

The current assessment is that the warmth of the equatorial Pacific will continue and that an El Niño of moderate strength seems more probable than a strong event; the likelihood of the sea surface temperature anomalies exceeding 2^0C is currently low.

Potentially, the biggest impact of the current El Niño in the coming three months is on the Indian monsoon rains. The latest predictions from the Met Office indicate that the probability of the monsoon rains being well-below normal (lowest quintile) is greater than 50% compared with the climatological probability of 20%. In other words the risk of a poor monsoon is 2-3 times greater this year than normal. So far the progress of the Indian monsoon rains bears this out, with a late and weak start to the season with less than 50% of normal rainfall in June over much of India.

Other possible impacts include:

(i) slightly weaker than average tropical cyclone activity in the Atlantic;
(ii) more active East Pacific tropical cyclone activity associated with the warmer ocean along the Peruvian coast;
(iii) greater typhoon activity associated with above average ocean temperatures in the tropical North West Pacific;
(iv) slightly increased likelihood of wetter than normal conditions over southern China;
(v) continuation of drought conditions in the western USA with associated risks of forest fires;
(vi) moderate increase in global mean temperatures, particularly in 2015.

The figures in this report will be updated to reflect the latest current conditions and the forecasts for the coming months. Further information can be found on the following sites:

http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/gpc-outlooks/el-nino-la-nina

http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/gpc-outlooks/el-nino-la-nina/ENSO-impacts

http://www.wmo.int/pages/themes/climate/consensus_driven_predictions.php

http://www.wmo.int/pages/prog/wcp/wcasp/enso_update_latest.html

1. BASICS OF EL NINO

Originally, the term El Niño (Christ Child) was used by Peruvian fishermen to denote the annual occurrence of a coastal warm current around Christmas. Today, the term El Niño is used to describe a much broader scale phenomenon associated with unusually warm water that occasionally forms across much of the tropical eastern and central Pacific Ocean. As the name suggests this phenomenon tends also to peak around Christmas.

El Niño events recur every few years as part of a naturally occurring cycle in which the opposite phase, La Niña, is characterised by colder than normal surface ocean temperatures in the tropical East Pacific. Both El Niño and La Niña are accompanied by major changes in the winds and pressure patterns across the tropical Pacific. These changes in the atmosphere are known as the Southern Oscillation, documented by Sir Gilbert Walker in 1924[1]. It took another 45 years before Jacob Bjerknes linked the Southern Oscillation to changes in ocean temperatures associated with El Niño and La Niña, and the term ENSO – El Niño Southern Oscillation - was born.

Under normal conditions, the equatorial Pacific Ocean has a pool of relatively warm water in the west and a shallower layer of relatively cool water in the east, maintained by, and in balance with, easterly surface winds (Figure 1). One can think of the easterly trade winds as piling up the warm surface waters in the West Pacific and bringing cooler water to the surface in the east through a process called ocean upwelling. Indeed, the sea surface height is ~ 0.5 meter higher in the West Pacific than it is in the East Pacific through the action of the winds on the ocean.

At the same time the warm waters of the West Pacific invigorate deep cumulus clouds, heavy rainfall and ascending air, which in turn strengthen the surface easterly winds across the equatorial Pacific, needed to feed these clouds with moisture. It is this relationship between the disturbed weather over the West Pacific and the surface easterly winds that is crucial for maintaining the normal state of the equatorial Pacific as depicted in Figure 1.

Although the term ENSO implies a dominant role for air-sea interaction, the key to understanding and indeed predicting El Niño and La Niña lies below the ocean surface in what is called the upper ocean mixed layer. As its name implies, the mixed layer is characterised by almost uniformly warm temperatures due to the mixing action of the winds and waves, and is typically several tens of meters deep. The mixed layer lies above a thin 'thermocline' layer where the temperature decreases rapidly with depth to reach those typical of the deep ocean. Under normal conditions the equatorial Pacific thermocline tilts upwards from west to east (Figure 1) due to the action of the easterly surface winds on the ocean.

One can think of the thermocline as a barrier between the warm, fresh water of the surface ocean and the cold, salty water of the deep ocean. That barrier can stay intact even when changes in surface winds force the ocean quite strongly; instead the thermocline moves up and down in response to the winds and either inhibits or enables cold water from the deeper ocean to come to the surface.

[1] The Southern Oscillation was identified by the British Meteorologist Sir Gilbert Walker in 1924. He noted that the surface pressures at Tahiti and Darwin were strongly related and that when the pressure was high over Tahiti it was low over Darwin and vice versa – the positive and negative phases of the Southern Oscillation. He also noted that when the Southern Oscillation was in its negative phase (i.e. pressure was high over Darwin) then the Indian Monsoon tended to be poor.

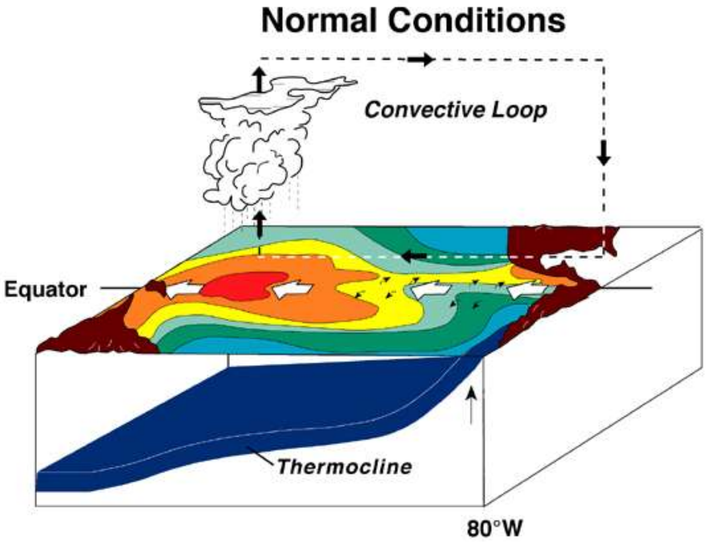

Figure 1: Normal conditions in the tropical Pacific Ocean.

During an El Niño, the easterly trade winds relax allowing the warm surface waters in the West Pacific to spread eastwards (Figure 2, left panel). At the same time the weakening of the easterlies also lessens the tilt of the ocean thermocline and reduces the ocean upwelling in the east, cutting off the supply of colder water to the surface. The net effect is that the Pacific Ocean becomes more uniform, with a thermocline that is less tilted from west to east. As the warmer surface waters spread eastwards so does the main area of disturbed weather; the main region of ascending air migrates from the West Pacific to the central and East Pacific and the surface winds adjust to feed the convection. This weakens the normal easterlies or may even reverse the winds from easterlies to westerlies. This change in the winds acts to strengthen and maintain the El Niño state.

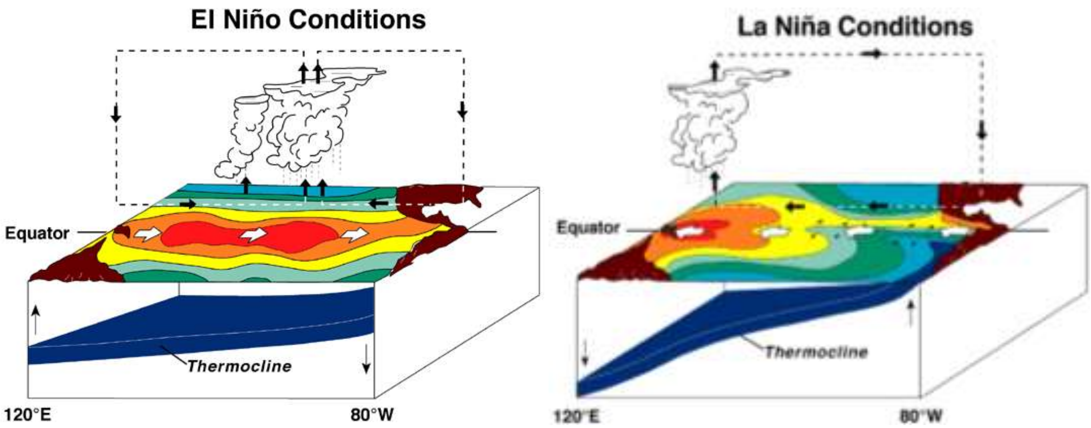

Figure 2: Schematics showing the typical changes in the tropical Pacific during El Niño (left panel) and La Niña (right panel).

The opposite phase of El Niño is La Niña (Figure 2, right panel). This describes a state where the easterly winds are stronger than normal, driving a more tilted thermocline, allowing stronger upwelling of cold water in the East Pacific and even greater confinement of the warm water in the West Pacific. La Niña can be considered as a reinforcement of the normal conditions in the Pacific (Figure 2), whereas El Niño represents a significant transformation away from the normal state. For this reason the global impacts of La Niña versus El Niño are not generally opposite or equal, and typically more profound during El Niño.

As much as one year in advance of the maximum surface warming in the East Pacific, the precursors of El Niño are often visible below the surface in the western Pacific Ocean, frequently as a response to a weakening of the easterly winds on or close to the equator. A system of tethered buoys[2] across the equatorial Pacific Ocean provides continuous information about the state of the upper ocean and the near surface winds and is vital for providing an early warning of an impending El Niño event.

The development of the 1997/98 El Niño is an outstanding example of the evolution of a major El Niño and its precursors (Figure 3). The El Niño was only manifest in the sea surface temperatures in early summer (Figure 3, right panel) yet the weakening of the easterlies in the West Pacific, often known as westerly wind events (Figure 3, left panel), and the subsequent changes to the thermocline[3] (Figure 3, middle panel) were already happening by the end of the previous year.

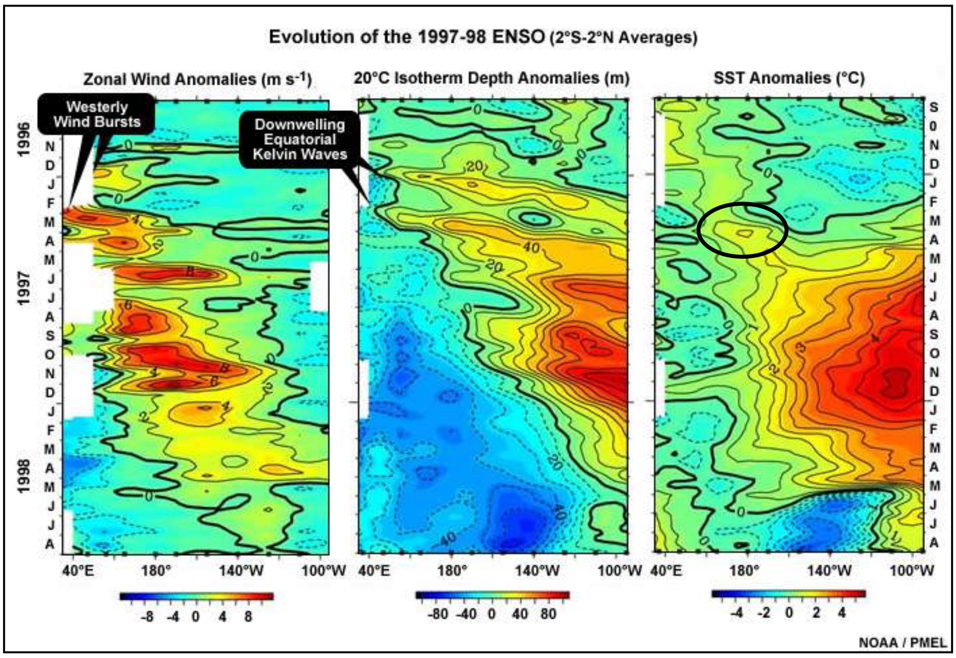

Figure 3: Observations from the El Niño monitoring array across the equatorial Pacific Ocean showing the evolution of the 1997/98 El Niño. Left panel: anomalies in the zonal (east-west) surface winds (m/s) with positive anomalies indicating westerly changes i.e. weaker easterlies. Middle panel: changes in depth (m) from the surface of where the temperature of the upper ocean reaches 20^0C (20^0C isotherm). This temperature is typical of the base of the ocean mixed layer, close to the thermocline. Positive anomalies therefore indicate a deeper than normal thermocline. Right panel: anomalies in the sea surface temperatures (^{0}C) showing the development of much warmer surface water in the East Pacific and slightly cooler water in the West Pacific.

[2] The El Niño monitoring array consists of approximately 70 moorings in the Tropical Pacific Ocean, sending oceanographic and meteorological data to shore in real-time via the Argos satellite system and funded by the USA and Japan. Standard moorings measure surface winds, air temperature, relative humidity, sea surface temperature, and ten subsurface temperatures from a 500m long thermistor cable.

[3] Changes to the thermocline are typically represented by the depth of the 20^0C (D20) isotherm. Positive depth anomalies indicate a deepening of the ocean mixed layer and depression of the thermocline. Conversely, negative anomalies indicate a shoaling (shallowing) of the ocean mixed layer with the thermocline being much closer to the surface. Positive anomalies in D20 in the East Pacific indicate a reduction in the upwelling of cold water to the surface whilst negative anomalies indicate that cold water is very likely to reach the surface.

The action of a westerly wind event is to induce ocean downwelling (sinking) and to increase the depth of the equatorial thermocline. This depression in the thermocline propagates eastwards along the thermocline with a well-defined speed associated with a theoretical structure known as an equatorial Kelvin wave[4]. The density difference across the thermocline between the warm, fresh upper ocean mixed layer and the cold, salty deep ocean sets the speed of propagation, with the wave taking typically 2 months to cross the equatorial Pacific from west to east (Figure 3, middle panel).

In late 1996, a westerly wind event excited a downwelling Kelvin wave, which propagated into the eastern Pacific, depressing the thermocline, cutting off the upwelling of cold water, and thus allowing the sea surface temperatures to rise and set the scene for an El Niño event. In March 1997, a second and much stronger westerly wind event excited another Kelvin wave, which reinforced the deepening of the thermocline in the East Pacific, further raising the sea surface temperatures. At the same time the surface currents generated directly by the westerly wind event pushed the warm surface waters of the West Pacific eastwards, extending the domain of the warmest waters and producing positive anomalies in sea surface temperature near the dateline (see black circle in Figure 3, right panel).

This warming of the central Pacific is a critical part of the evolution of El Niño by helping to establish the changes in the surface pressure field (the Southern Oscillation) that predispose the near surface winds to be more westerly than normal. From there on, the sequence of positive feedbacks between the atmosphere and the surface ocean (known as Bjerknes feedbacks), and between the surface winds and the thermocline come into play, and El Niño intensifies through the summer and autumn to reach its maximum around Christmas. The name 'ENSO' is a reminder that the close interaction between the atmosphere and ocean is an essential part of the phenomenon.

Even during the development of an El Niño event, the seeds of its destruction are being sown in the western Pacific through the dynamic adjustment of the ocean. The eastward extension of the subsurface cold anomalies (Figure 3, middle panel) brings the thermocline closer to the surface and starts the gradual erosion of the surface warm anomalies. This initiates a reversal of the chain of the Bjerknes feedback, which acts to drive the coupled system into a La Niña event (Figure 3, right panel). The timescale of El Niño (roughly 12 months) is set by the adjustment timescales of the thermocline, evident in Figure 3.

[4] Discovered by Lord Kelvin, the Kelvin wave is a special type of gravity wave that is affected by the Earth’s rotation and trapped at the Equator or along lateral vertical boundaries such as coastlines or mountain ranges. Coastal Kelvin waves propagate along coasts in the Northern Hemisphere such that the coast is to the right of the alongshore direction of propagation (and to the left in the Southern Hemisphere). Equatorial Kelvin waves behave somewhat as if there were a wall at the equator due to the Coriolis force going to zero – so that the equator is to the right of the direction of along-equator propagation in the Northern Hemisphere and to the left of the direction of propagation in the Southern Hemisphere, both of which are consistent with eastward propagation along the equator.

2. THE 2014/15 EL NINO

Very similar to the sequence of events that preceded the 1997/98 El Niño, the beginning of 2014 saw the development of westerly wind events in the West Pacific which excited strong Kelvin waves along the thermocline (Figure 4). These westerly wind events were part of the eventual breakdown of the anomalously wet conditions that had existed across Indonesia and the West Pacific during the winter, and that had been a strong driver of the extreme winter weather conditions experienced across North America and the UK[5].

The strength of the initial Kelvin waves was similar to the precursors of the 1997/98 El Niño (Figure 3, but note the different scales for SST and isotherm depth), and represented the biggest adjustment to the thermocline in the central Pacific since that event. It raised the possibility therefore of the development of a major El Niño in the coming months with potentially significant disruption to the climate.

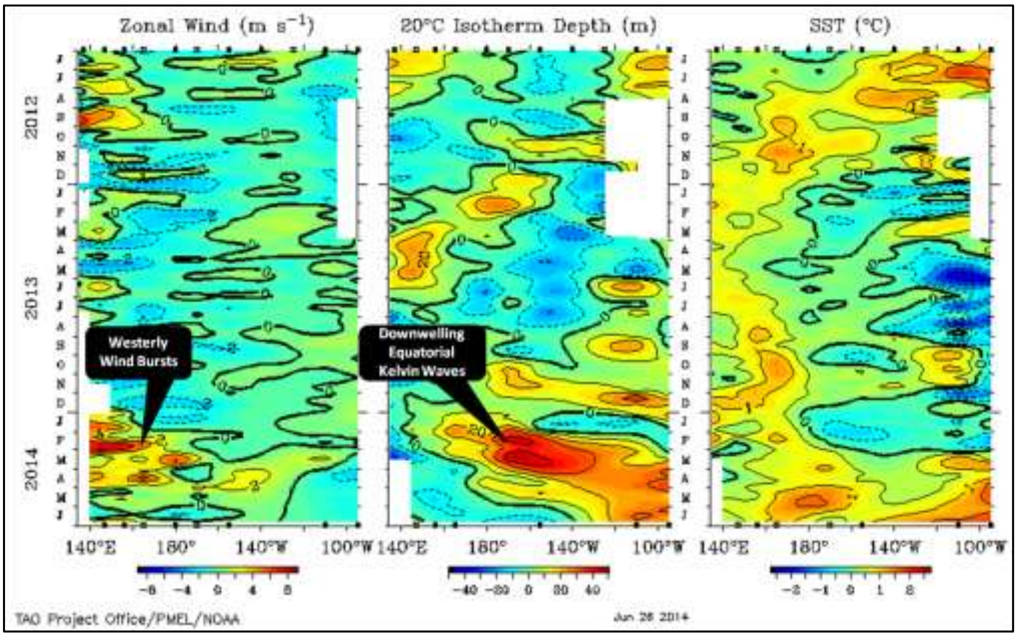

Figure 4: As Figure 3, showing the latest observations (as of 26 June 2014) of the evolution of the current El Niño. Note the different ranges in the colour bars for sea surface temperature (SST) and depth of the 20^{0}C isotherm.

In the early months of 2014, as expected, once the Kelvin waves reached the East Pacific, the sea surface temperatures increased, westerly wind anomalies were established over the central and West Pacific, and the Southern Oscillation became negative (Figure 5), associated with an area of disturbed weather developing just west of the dateline.

However, unlike the 1997/98 event, the positive atmosphere-ocean feedbacks have not continued to develop as strongly. The surface winds have not transitioned to more westerly anomalies (Figure 4, left panel) – indeed easterly anomalies were established during June - and the initial burst of Kelvin wave activity has not been followed by further strong events (Figure 4, middle panel).

[5]Met Office Briefing Paper on 'The Recent Storms and Floods in the UK'. See http://www.metoffice.gov.uk/research/news/2014/uk-storms-and-floods

As Figure 5 shows, the Southern Oscillation Index (SOI) has fluctuated between positive and negative values, in contrast to the growth of the 1997/98 El Niño where the SOI changed rapidly to persistent negative values. This means that the air-sea interactions (Bjerknes feedbacks) that are a critical part of the development of El Niño have yet to come into play this year. This suggests that any El Niño event in the coming months is unlikely to be as strong as that in 1997/98.

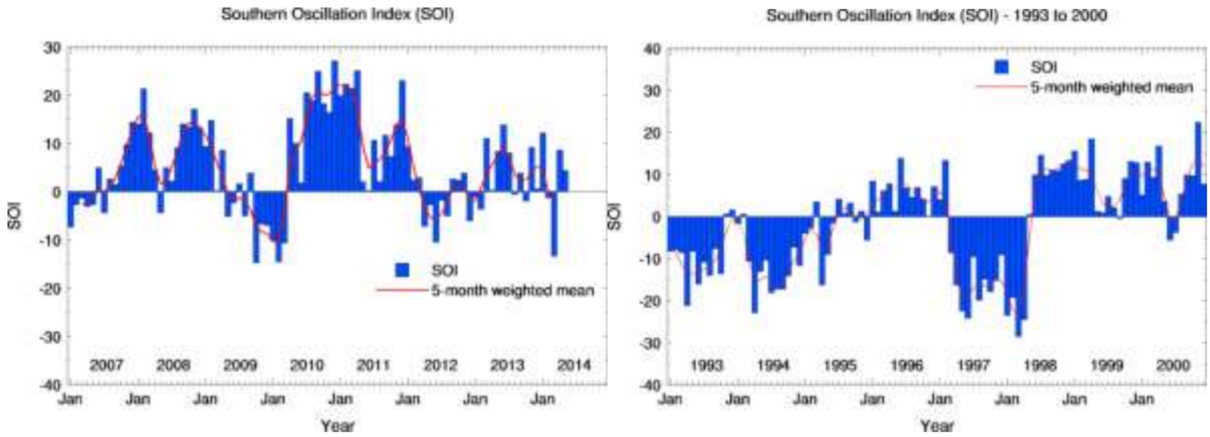

Figure 5: Timeseries of the monthly Southern Oscillation Index (SOI) defined as the difference in atmospheric pressure (mb) between Tahiti and Darwin. Negative values of correspond to El Niño conditions. Left panel shows the current values since 2007 and the right panel shows the values observed through the 1997/98 El Niño. From Bureau of Meteorology, Australia.

This hypothesis is supported by the latest predictions from the Met Office state-of-the-art climate model, issued at the end of June and initialised with the latest ocean and atmosphere conditions (Figure 6).

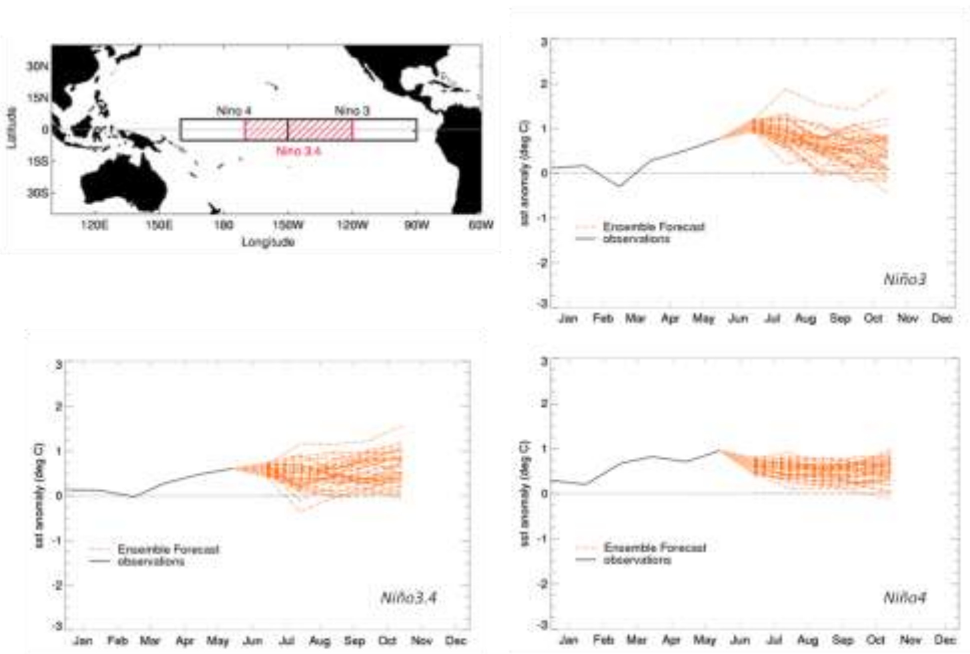

Figure 6: Latest predictions of El Niño indices from the Met Office seasonal forecast system initialised in June 2014. The indices relate to sea surface temperature anomalies in the three areas shown in the top left figure. Black line is the observed anomalies and the dashed orange lines show the individual forecasts from the ensemble seasonal prediction system.

These forecasts, taken alongside those produced by other centres, confirm the high probability of an El Niño event in the coming months, but suggest that the probabilities of the sea surface temperature anomalies reaching 2^0C are currently low. For comparison, during the major El Niño's of 1982/83 and 1997/98, the Niño3 index exceeded 3^0C. The current conditions in the tropical Pacific, seen in Figure 3, also suggest that a strong East Pacific El Niño is unlikely. The forecasts suggest that Niño3 SSTs may cool after the summer, whereas the Niño3.4 SSTs are likely to stay warm. The importance of this for the potential impacts of any El Niño is discussed in the next section.

3. GLOBAL IMPACTS OF EL NINO

While the global climate system contains many processes and many modes of variability, the El Niño Southern Oscillation (ENSO) is by far the dominant feature of climate variability on inter-annual timescales, and its influence on global weather and climate patterns is substantial. These changes can last for several months, and can lead to significant socio-economic impacts affecting infrastructure, agriculture, water resources, health and energy supplies, for example. An important feature of the ENSO cycle is that its evolution is predictable several months in advance, so the impacts can be anticipated and decisions can be taken to mitigate adverse effects or take advantage of favourable aspects.

During ENSO events the changes in sea surface temperature are closely bound to changes in atmospheric circulation (i.e. wind and pressure patterns) and in temperature and rainfall. Through atmospheric dynamics, these changes extend well beyond the tropical Pacific region by producing anomalous regions of ascent and descent all around the global tropics (Figure 7). These regions of ascent and descent, along with the inferred upper and lower level winds, are known as the Walker Circulation, after Sir Gilbert Walker.

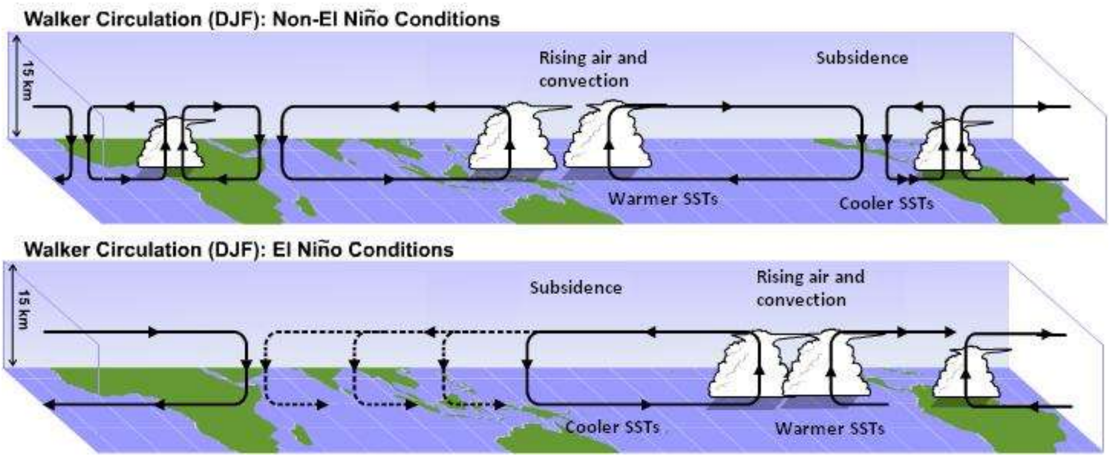

Figure 7: Schematic of the changes in the longitudinal vertical circulations around the global tropics during winter for normal conditions (upper panel) and for El Niño conditions (lower panel). Image from Penn State University.

By analysing conditions experienced during many past events, statistics of the impacts can be produced (Figure 8)[6]. These maps summarise the main impacts on

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[6] For temperature the regions selected are areas where a substantial impact is likely, in the sense that the seasonal value will be in the top (or bottom) one third of observed values centred on the months indicated, with approximately a greater than 50% chance that the impact will occur if the ENSO event is active, based on historical evidence. For example, for a region marked 'warmer likely' in December in El Niño conditions, this means approximately a greater than 50% chance that the temperature will be in the top third of temperatures observed in the November-December-January season. The criterion for El Niño active is Niño3.4 regional sea surface temperature in the top 25% of observed values in the corresponding seasons. For precipitation, for which data are more limited and probability estimates are more uncertain, analyses of composites were also used to determine regions and seasons that tend to be influenced by ENSO events. *From Davey M. K., A. Brookshaw, S. Ineson, 2014: The probability of the impact of ENSO on precipitation and near-surface temperature. Climate Risk Management,* ***1****, 5-24.*

seasonal precipitation and near-surface temperature over land areas for El Niño events. For each region marked, the colour indicates the tendency and the text indicates the seasonality of the impact. The maps are based on analyses of historical datasets extending over several decades and on information in peer-reviewed publications.

Those associated with changes in rainfall tend to be the most profound. Although the tropical belt tends to bear the brunt of the impacts due to changes in the Walker Circulation, the extratropics can also be affected substantially. Even over the UK and western Europe the influence of an El Niño can be felt, particularly in winter, although the impacts tend to be weaker and less predictable because of the distance from the El Niño itself[7].

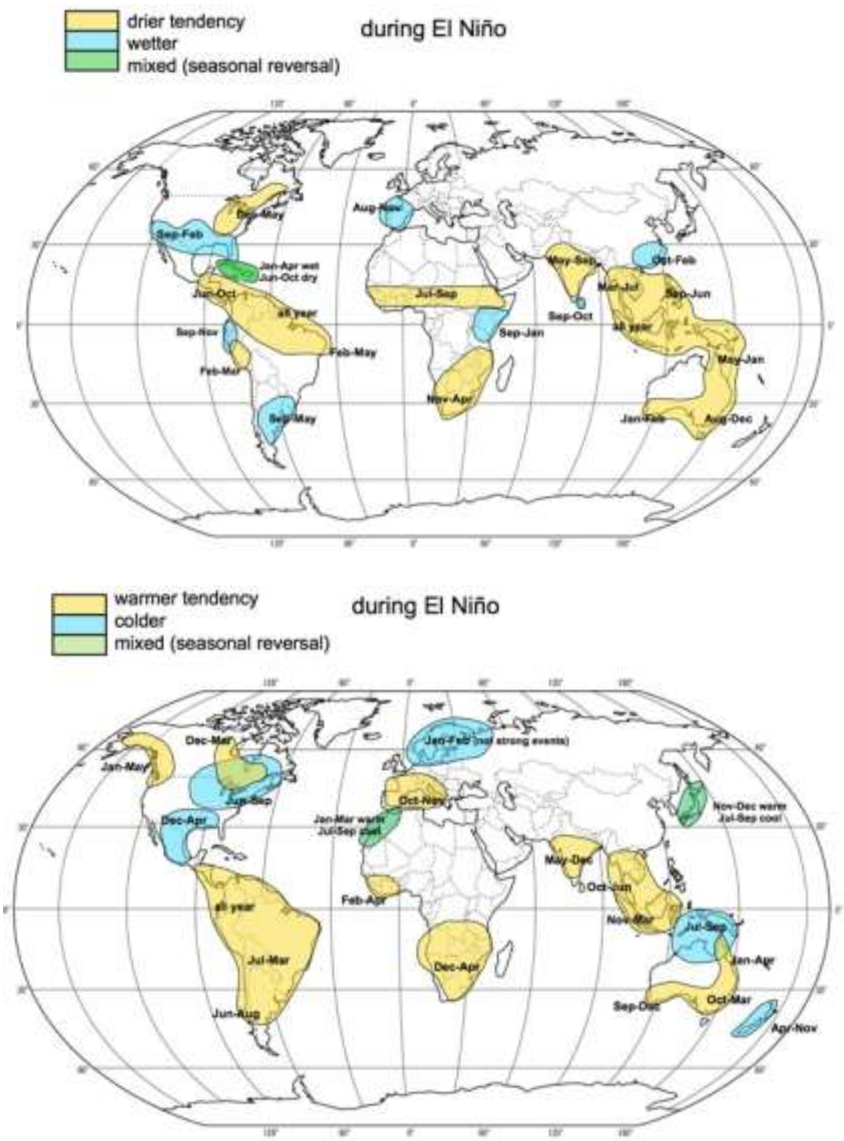

Figure 8: Typical seasonal impacts of El Niño in terms of changes in rainfall (top panel) and temperature (lower panel)[8].

[7] Sarah Ineson and Adam Scaife, 2009: The role of the stratosphere in the European climate response to El Niño. *Nature Geoscience* **2**, 32 - 36

[8] M. K. Davey, A. Brookshaw, S. Ineson, 2014: The probability of the impact of ENSO on precipitation and near-surface temperature. *Climate Risk Management*, **1**, 5-24.

The sea surface temperatures of the tropical Atlantic and Indian Oceans are also affected by the adjustments to the Walker Circulation during El Niño (see Figure 7) and can cause related impacts. Changes in the winds and the clouds over the adjacent oceans cause the surface temperatures to rise over the months during and following the peak of El Niño. This extends and prolongs the impacts into the following year even after the peak of El Niño has passed.

Not all impacts are detrimental however and the effects on the Atlantic hurricane season have been well documented (Figure 9). Due to changes in the upper level winds associated with the perturbations to the Walker Circulation, the development of hurricanes can be inhibited in El Niño years.

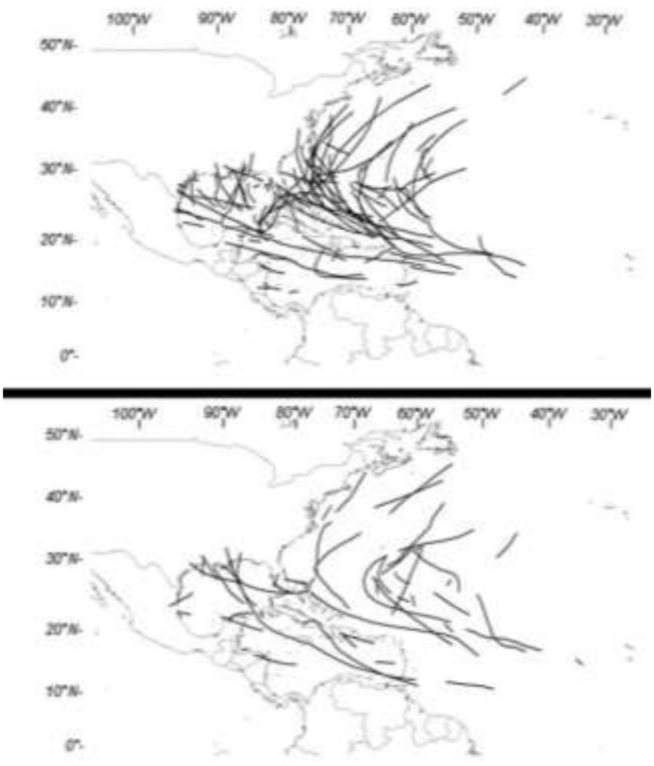

Figure 9: Tracks of major Atlantic hurricanes that occurred during La Niña (top panel) and El Niño (bottom panel) years. Eighty-two major hurricanes and 186 major hurricane days occurred in the 26 La Niña years compared with 43 major hurricanes and 84.75 major hurricane days in the 28 El Niño years. The absence of major hurricane tracks near the East Coast is especially notable in El Niño years. From Klotzbach (2011)[9]

It is important to note, however, that each ENSO event is different and has its own evolution and special characteristics. Figures 8 and 9 do not distinguish between the different 'flavours' of El Niño that are now known to exist. Over recent years there has been a growing body of evidence to suggest that two distinct types of El Niño occur, which, because of the different locations of the maxima in ocean warming and associated atmospheric heating, can be classified as eastern (EP) and central (CP) Pacific warming events (Figure 10). CP events are often referred to as El Niño Modoki events[10].

The identification of these two distinct types of El Niño is important because this offers new opportunities to examine and discriminate the global impacts of El Niño[11].

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[9] Philip Klotzbach, 2011: El Niño–Southern Oscillation's Impact on Atlantic Basin Hurricanes and U.S. Landfalls. *J. Climate*, **24**, 1252–1263.

[10] Karumuri Ashok and others, 2007: El Niño Modoki and its possible teleconnection. J. Geophysical Research: Oceans, 112, DOI: 10.1029/2006JC003798

[11] Jin-Yi Yu and Yuhao Zou, 2013. The enhanced drying effect of Central-Pacific El Niño on US winter *Environ. Res. Lett.* **8** doi:10.1088/1748-9326/8/1/014019

It is notable that the location of El Niño has shifted more to the central Pacific in recent decades. Whether that is due to decadal changes in the mean state of the Pacific Ocean, associated with the Pacific Decadal Oscillation, for example, or whether this is an emerging signal of climate change is unclear[12].

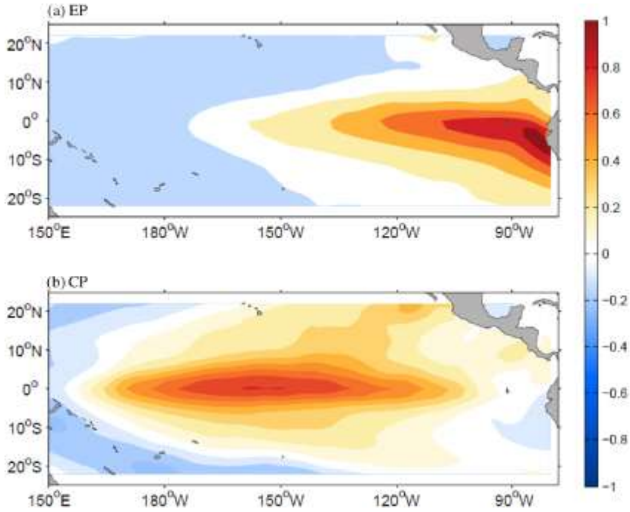

Figure 10: Normalised patterns of sea surface temperature anomalies associated with El Niño events that are concentrated in the East Pacific (EP, e.g. 1997/98) and those that are concentrated in the central Pacific (CP, e.g. 2009/10). The colour scaling shows the relative intensity of the two types of El Niño. From Yu and Zou 2013.

What is known is that CP El Niño events affect the global climate system differently from EP events[13]. For example, in the US winter there is less precipitation than is typically produced by traditional EP El Niño events, particularly over the Ohio–Mississippi Valley, Pacific Northwest and Southeast. This is related to a more southward displacement of the Pacific jet stream that controls the location of winter storms. Likewise the impacts of a CP (Modoki) El Niño may be substantially different around the Pacific rim (Figure 11)[13], although the sample size in this study is small. Droughts in the western USA tend to be severe during the summer months, and the emergence of the CP El Niño in recent decades may be one factor contributing to the recent prevalence of extended droughts in the USA.

Of considerable interest is the finding that North Atlantic tropical cyclone activity is not substantially affected during CP events and may even be enhanced – quite the opposite of the conventional understanding of impacts of El Niño described above[14][15] (Figure 12). Differences are shown to be associated with the modulation of vertical wind shear in the main tropical cyclone development region over the tropical Atlantic forced by different teleconnection patterns emanating from the Pacific when the maximum warming occurs in the central Pacific.

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[12] Tong Lee and Michael J. McPhaden, 2010. Increasing intensity of El Niño in the central-equatorial Pacific. Geophysical Research Letters, Volume 37, Issue 14

[13] Hengyi Weng, Karumuri Ashok, Swadhin K. Behera, Suryachandra A. Rao and Toshio Yamagata, 2007: Impacts of recent El Niño Modoki on dry/wet conditions in the Pacific rim during boreal summer. Climate Dynamics DOI 10.1007/s00382-007-0234-0

[14] H-M Kim, P. J. Webster and J. A. Curry, 2009: Impact of Shifting Patterns of Pacific Ocean Warming on North Atlantic Tropical Cyclones. Science, 325, 77-80. DOI:10.1126/science.1174062

[15] S. Larson and others, 2012: Impacts of non-canonical El Niño patterns on Atlantic hurricane activity. Geophys. Res. Letters, DOI: 10.1029/2012GL052595

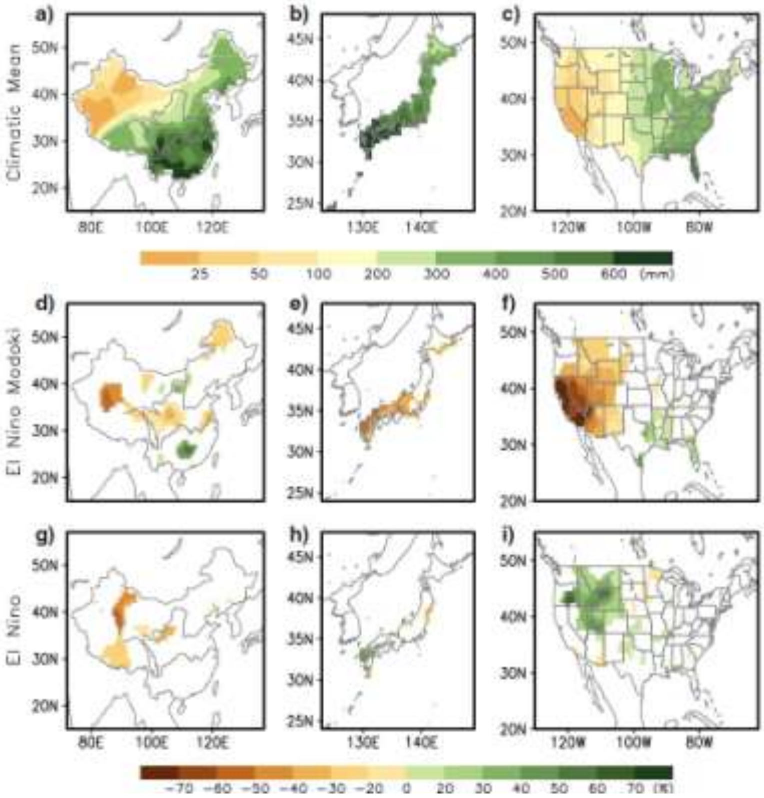

Figure 11: Comparison of the impacts of the three largest East Pacific (EP, bottom row) and three largest central Pacific (CP/Modoki, middle row) El Niño events on summer (June, July, August) rainfall around the Pacific rim. Top row shows the climatic mean in terms of mm and the lower panels show the typical anomalies as a % of the climatic mean. Only values which are 80% significant and above are plotted. (From Weng et al. 2007)

An important aspect of El Niño is its influence on the global mean surface temperature, through its global teleconnections and remote influence on the Atlantic and Indian Ocean temperatures discussed above. The major El Niño of 1997/98 elevated the global mean surface temperature by at least 0.2^{0}C. Since then the increase in global mean surface temperatures has been small and this has been linked in part to decadal changes in the circulation of the Pacific Ocean[16].

It has also been noted recently that CP El Niño events do not have the same impact on global mean surface temperatures as EP El Niño events[17]; global mean surface temperatures are, typically, anomalously warm during and after EP events, but not in CP or mixed CP/EP events. It is also the case that since 1998, El Niño has been dominated by CP events, and this recent paper[12] suggests that since the late 19th century, periods of slowdown in the rate of global mean surface warming typically contain only CP El Niño events, and no EP events.

Furthermore, there is evidence to link the prevalence of one type of El Niño or the other to decadal variations in the mean state of the Pacific associated with the Pacific

[16] Met Office Briefing Paper on ‘The Recent Pause in Global Warming (2): What are the potential causes?’ See: http://www.metoffice.gov.uk/media/pdf/q/0/Paper2_recent_pause_in_global_warming.PDF

[17] S. Banholzer and S. Donner, 2014: The influence of different El Nino types on global average temperatures. Geophys. Res. Lett., 41, 2093-2099.

Decadal Oscillation (PDO)[18]. The current cold (negative) phase of the PDO is likely to favour La Niña or CP El Niño events, very much as has been observed since 2000, by restricting wind anomalies and convection to the central Pacific[19]. In fact 80% of CP El Niño events since 1950 have occurred since 1990.

What this discussion emphasises is that our understanding of El Niño has grown substantially in recent years and that its impacts depend on subtleties in the pattern of sea surface temperature changes in the tropical Pacific. This suggests that using simple metrics of El Niño to make empirical predictions of potential impacts may miss some important factors.

[18] D. C. Verdon and S. W. Franks, 2006: Long-term behaviour of ENSO: Interactions with the PDO over the past 400 years inferred from paleoclimate records. Geophys. Res. Lett., 33, DOI: 10.1029/2005GL025052

[19] Xiang et al. 2012: A new paradigm for the predominance of standing Central Pacific Warming after the late 1990s

4. POSSIBLE IMPACTS OF AN EL NINO IN 2014/15

As a first guide, the global effects of El Niño outlined in Figure 8 could be used as a starting point to consider the potential impacts of an El Niño in the coming months. However El Niño constitutes just one (albeit very important) influence on the climate system, but as is always the case, other factors come into play. Also we now know that there are different flavours of El Niño that can have diverse impacts on the climate system. For these reasons, the typical response to El Niño should not be seen as inevitable. Rather, El Niño and La Niña events should be regarded as shifting the odds in favour of a typical response that may, for example, increase the risk of heavy rainfall and consequent damage in a particular region/season of interest.

It is unclear at this stage whether the developing El Niño will be predominantly an EP or CP event. The early stages of its development have been close to an EP El Niño (Figure 3), but more recently, warming in the central Pacific has emerged, symptomatic of a CP event. The latest map of sea surface temperature anomalies (Figure 13) shows that the central and West Pacific Ocean remains warmer than normal, in contrast to the cooling that is expected for EP El Niño events (Figure 10, upper panel). This is likely disrupting the atmospheric changes and positive Bjerknes feedbacks on El Niño. Also the warm signal in the East Pacific is confined to the near coastal regions and has not extended as far to the west as would be expected. This is consistent with the predictions for the Niño3 index shown in Figure 6, which suggest that a decline in the anomalies might even occur through the remainder of the year, and that therefore a strong EP El Niño event is unlikely.

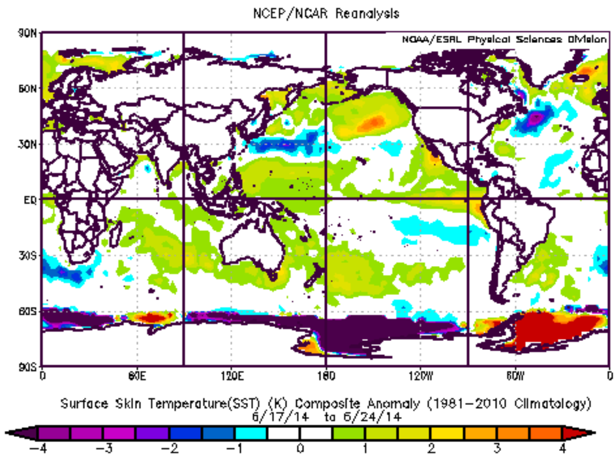

Figure 13: Latest observed sea surface temperature anomalies (^{0}C) for 17-24 June 2014.

As already noted, El Niño is only one of the factors that may come into play to affect the climate system over the coming months. A notable feature of the latest sea surface temperatures is the warmth of the north-west tropical Pacific, which may have an impact on the East Asian monsoon and typhoon activity that is atypical of what might be expected in (EP) El Niño years.

Also, Figure 13 shows that the ocean temperatures continue to be much warmer than normal over the extra-tropical North East Pacific, as a response to the persistent changes in the winds associated with the negative phase of the Pacific Decadal Oscillation (PDO).

So what is the current state of the PDO and how might this affect the evolution of this El Niño? As the El Niño started to develop in the early months of this year, the PDO index changed from negative to positive raising the possibility that the PDO might be changing its phase. However, closer examination of the pressure patterns across the North and South Pacific suggest that the negative phase of the PDO is still in force.

In addition the tropical West Pacific remains warmer than normal, typical of negative PDO states. Taken together with the evidence that the negative phase of the PDO inhibits the Bjerknes feedbacks, essential for the development of a strong EP El Niño, then it seems more likely that the climate system will experience a weak to moderate CP El Niño in line with the latest predictions.

Assessments of the potential effects of an El Niño event that is in progress are best based on forecasts that take into account all known details of the recent and present state of the climate system. The latest forecasts from the Met Office seasonal prediction system show substantial changes in tropics-wide rainfall with notable decreases in the Indian monsoon. The probability of the monsoon rains being well-below normal (lowest quintile) is greater than 50% compared with the climatological probability of 20%. In other words the risk of a poor monsoon is 2-3 times greater this year than normal.

So far the progress of the Indian monsoon rains bears this out, with a late and then weak start to the season, with less than 50% of normal rainfall (Figure 14). Whilst this is still early in the season such deficits are already unusual. The link between El Niño and drought in India is well documented, robust and understood. As with all impacts of El Niño, the scale of the anticipated drought depends on many factors, including subtle differences in the pattern of El Niño[20]. For instance, the very strong El Niño of 1997/98 actually led to more rain over India[20], whilst during the 2009 El Niño, which was relatively weak, the monsoon was badly affected, with a 23% reduction in rainfall and an estimated 12% fall in total crop harvest.

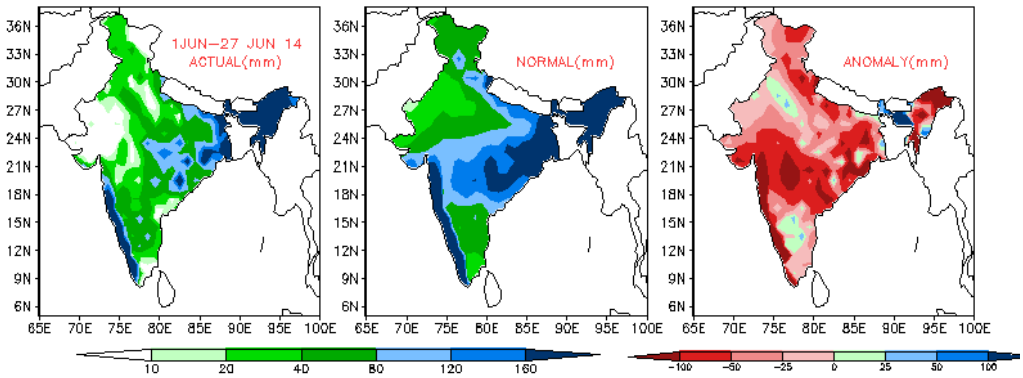

Figure 14: Progress of the Indian monsoon rains up to 27 June 2014. From Indian Meteorological Department.

A weaker than normal Indian monsoon has profound impacts on food production, energy supply and the economy of India. As has been widely reported recently, a weak monsoon could push up food prices and with it inflation, testing the new government's ability to promote economic growth. This year's monsoon rainfall will be a crucial variable in calibrating monetary policy by the central bank.

Bearing in mind that an El Niño of moderate strength seems more probable than a strong EP event, and noting that temperatures in the tropical North West Pacific Ocean are above normal, other possible impacts may include:

(i) slightly weaker than average tropical cyclone activity in the Atlantic, although this may be tempered by the possibility of a CP rather than EP El Niño;

(ii) more active East Pacific tropical cyclone activity associated with the warmer ocean along the Peruvian coast;

[20] Slingo, J. M. and H. Annamalai, 2000: 1997: The El Nino of the century and the response of the Indian Summer Monsoon. *Mon. Weath. Rev.,* **128**, 1778-1797.

(iii) greater typhoon activity in the West Pacific associated with above average ocean temperatures in the tropical North West Pacific;

(iv) slightly increased likelihood of wetter than normal conditions over southern China, as part of the response to a CP El Niño (Figure 11);

(v) continuation of drought conditions in the western USA with associated risks of forest fires (Figure 11);

(vi) moderate increase in global mean temperatures, particularly in 2015.

In summary, over the next three months the climate system will be affected by the changes currently taking place in the equatorial Pacific, but these are unlikely to be as profound as those in 1997 and probably closer to those experienced in 2009. In 2009 the Indian Summer Monsoon was very adversely affected and it is anticipated that this may be the most profound impact of the current event through the next few months. Beyond that, the impacts of the El Niño will depend on how it continues to evolve, noting that any impacts on the UK are mainly felt during the winter months.

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