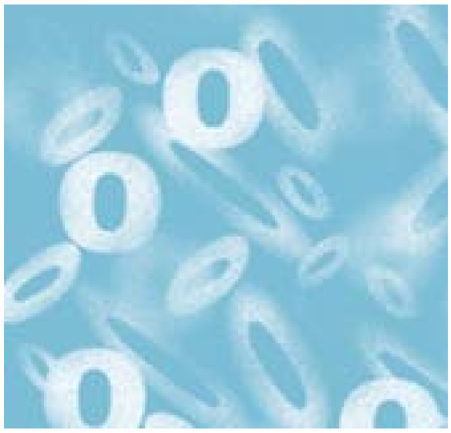

Peculiarities of Murray Valley encephalitis (MVE) epidemics in south–eastern Australia: the Indian Ocean dipole (IOD) as a predictor of epidemics

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The Murray Valley encephalitis virus (MVEv) is endemic in Papua New Guinea and northern Australia where it survives primarily in mosquito-bird cycles. Humans and other animals inadvertently become infected after being bitten by mosquitoes carrying the virus. Severe human infection in the form of MVE, occurs as single occurrences or small clusters of cases, with outbreaks commonly preceded by heavy local rainfall which encourages proliferation of the mosquito vector of MVE, *Culex annulirostris*.

In contrast, the epidemiology of human MVE in the temperate zone of south-eastern Australia differs in a number of respects. The virus, now believed to be endemic in this region albeit in low density, is only detectable under certain climatic conditions.[1,2]

Disease characteristically occurs in epidemic form in the south-east (1917, 1918 (62 cases), 1925, 1951 (45 cases) and 1974 (42 cases)). During these epidemics, MVE also commonly occurred in Queensland reflecting heavy rainfall in north-eastern Australia, and in 1974, additionally in the Northern Territory and Western Australia, associated with widespread rainfall across the continent.[1] Post-epidemic serological surveys demonstrated that human infection with MVEv was widespread, with a ratio of about 1:800, clinical to sub-clinical cases.

A relationship to patterns of excess rainfall also is unique to epidemics of MVE in south-east Australia. Anderson pointed this out first:[3] "During the period 1913 to 1952, the disease had been recognised in the valleys of the Murray River and its tributaries on only four occasions. These were during the latter months of the summers of 1916–17, 1917–18, 1924–25 and 1950–51. During the same forty years there had been five years of grossly excessive spring rainfall in northern and eastern Australia. These were 1916, 1917, 1924 and 1950, all of which directly preceded outbreaks of encephalitis, and 1933." That encephalitis was not recorded in 1933–34, shows that this was not an 'all or none phenomenon'. In 1978, Forbes[4] postulated that two consecutive seasons of high rainfall, in all four major northern catchments of the Murray Darling Basin, was a prerequisite for MVE to occur along the Murray River. Unfortunately, this model proved unreliable when it incorrectly predicted a MVE outbreak in the summer of 2000–2001.[1] It is notable that both Anderson and Forbes mentioned little about the importance of the amount (or lack) of rainfall in the Murray-Darling Basin or over the southern catchments of the Murray River.

Studies of tropical ocean-atmospheric phenomena provide some understanding of south-east Australia's weather patterns. The El Niño-Southern Oscillation or ENSO phenomenon, is of predictive value for rainfall in Australia.[5] Early in the 20th century it was discovered that, in some years, atmospheric pressure deviated from normal in the south-eastern tropical Pacific Ocean (South American area) and over the Indonesian region. The pressure difference between east and west could weaken (an El Niño event); or the opposite atmospheric changes could occur (a La Niña event). This aperiodic modulation of the southern Pacific atmospheric pressures was coined the 'Southern Oscillation'. Observations show that the Sea Surface Temperatures (SSTs) on the eastern side of the Pacific are normally remarkably cold for such equatorial latitudes, whereas those in the western Pacific are very warm. The large-scale wind field over the equatorial Pacific Ocean, the trade winds, driven by the atmospheric pressure across the Pacific Ocean basin, can account for the observed SST distribution: in normal years, the trade winds across the Pacific blow from east to west, essentially 'pushing' warm waters westward and raising the sea level in the west. In the eastern Pacific, cooler waters upwell from depth to replace the waters that were moved offshore. Enhanced convective activity and rainfall is associated with the warm waters in the west, as warm moist air rises there. In contrast, comparatively little rainfall occurs over the cool ocean temperatures in the eastern Pacific. During El Niño events, changes in the pressure difference between the eastern and western Pacific occurs, which considerably weaken (or even reverse) the trade winds. This weakening of the winds causes the warm waters in the western Pacific to move eastward towards South America, where upwelling ceases. At the height of an El Niño event, unusually warm ocean temperatures across the central and eastern Pacific Ocean are seen. The convective activity moves eastward with the warm waters, causing heavy rains and flooding in the eastern Pacific and over Central America.

* The author is deceased having passed away in between writing and the subsequent publishing of this article

El Niño events were subsequently shown to have wider impacts with sustained warming over a large part of the central and eastern Pacific Ocean, which influences weather patterns across the world. El Niño events frequently cause reduced rainfall across eastern and northern Australia, particularly during winter, spring and early summer; they occur irregularly (about every four to seven years) and may persist for 12–18 months. With a La Niña event, there is extensive cooling of the central and eastern Pacific Ocean associated with broadly opposite meteorological changes to those which occur in an El Niño event. La Niña events tend to follow an El Niño event and from autumn onwards they often bring wetter than normal conditions across much of the eastern half of Australia. Various indices have been devised to provide a numerical scale to quantify the strength of Southern Oscillation changes, such as the Southern Oscillation Index (SOI). The SOI is based on the sea level barometric pressure difference between Tahiti and Darwin. A moderate to strongly negative SOI is usually characteristic of an El Niño event, whereas a moderate to strongly positive SOI is usually indicative of a La Niña event.

The problem with using ENSO data to predict MVE outbreaks in south-east Australia is that although a La Niña event may predict rainfall in northeastern/ eastern Australia; this may not reach the south-eastern region. For example, in 2008 a La Niña event resulted in great floods across north-east Australia causing the Darling River to flow again, but these floods failed to reach southern New South Wales.[1] A similar situation arose in the first quarter of 2009, when several record breaking floods occurred in Queensland whilst south-eastern Australia remained in the grip of the 'Big Dry' drought.

The Indian Ocean Dipole[6] (IOD), first coined in 1999, is, like ENSO, another aperiodic oscillation of the coupled ocean-atmosphere system, but it is situated in the tropical Indian Ocean. It is quantified by an index which has positive and negative phases and is based on the difference between the SSTs in the western and eastern tropical Indian Ocean. The positive phase is characterised by unusually cool SST in the south-eastern equatorial Indian Ocean and anomalous warming of the SST in the western equatorial Indian Ocean. This changes the region of convection, bringing heavy rainfall to east Africa, and severe droughts to Indonesia and Australia (positive dipole mode or a positive IOD event). When this pattern is reversed with anomalous cool waters in the west and warm SST in the eastern Indian Ocean in the Timor Sea (figure 1a), the circulation and winds across the region change, bringing wet conditions to Australia and Indonesia (a negative IOD event).

In a paper published in early 2009, it was concluded, "that Indian Ocean variability, more than ENSO, is the key driver of the major droughts over the past 120 years in the region of southeastern (sic) Australia examined in this study".[7] Some relevant comments in this paper were:

- South-east Australia was defined as the land region enclosed within 35°–40°S and 140°–148°E. (This approximates to the area bound by Ouyen in northern Victoria to Bass Strait in the South, and Murray Bridge (South Australia) in the west to just east of the Victorian Alps, in the east – ie a large part of the State of Victoria and a small portion of South Australia).
- There is increasing evidence that the IOD can occur independently of ENSO.
- In El Niño years reduced rainfall occurs over the eastern half of Australia. During La Niña years onshore moisture flows cause enhanced precipitation along the north-east and east. But in the south-east of the country pure La Niña events only show moderate above-average rainfall.
- Negative IOD events are characterised by above-average rainfall over south-eastern Australia (as defined), resulting from an interaction between the tropics and temperate zone that increases moisture transport onto the region (see figure 1b, c); this interaction is often visible as north-west cloud-bands.
- By contrast, the major droughts which have occurred in south-eastern Australia, the Federation Drought (1895–1902), the World War II Drought (1937–1945) and the Big Dry (1995–2009 and continuing) were driven by Indian Ocean variability. During these periods the IOD has remained persistently positive or neutral.
- The intensity of the Big Dry is exacerbated by recent higher air temperatures.
- IOD events may be predictable out to several months in advance.
- The characteristics of positive and negative IOD events might be changing.

These findings provided an unexpected opportunity to test whether there was any relationship between the above-average rainfall in south-eastern Australia (as defined) caused by negative IOD events, and the occurrence of past MVE outbreaks in 1917, 1918, 1925, 1951, 1956, and 1974. Indeed, these years all fell into the broadly 'wet' categories (La Niña, negative IOD, or La Niña co-occurring with negative IOD), neutral or El Niño. In addition, none of the MVE outbreaks occurred during years with a positive IOD event. Based on these findings, the IOD has a predictive value for future MVE epidemics in south-eastern Australia.

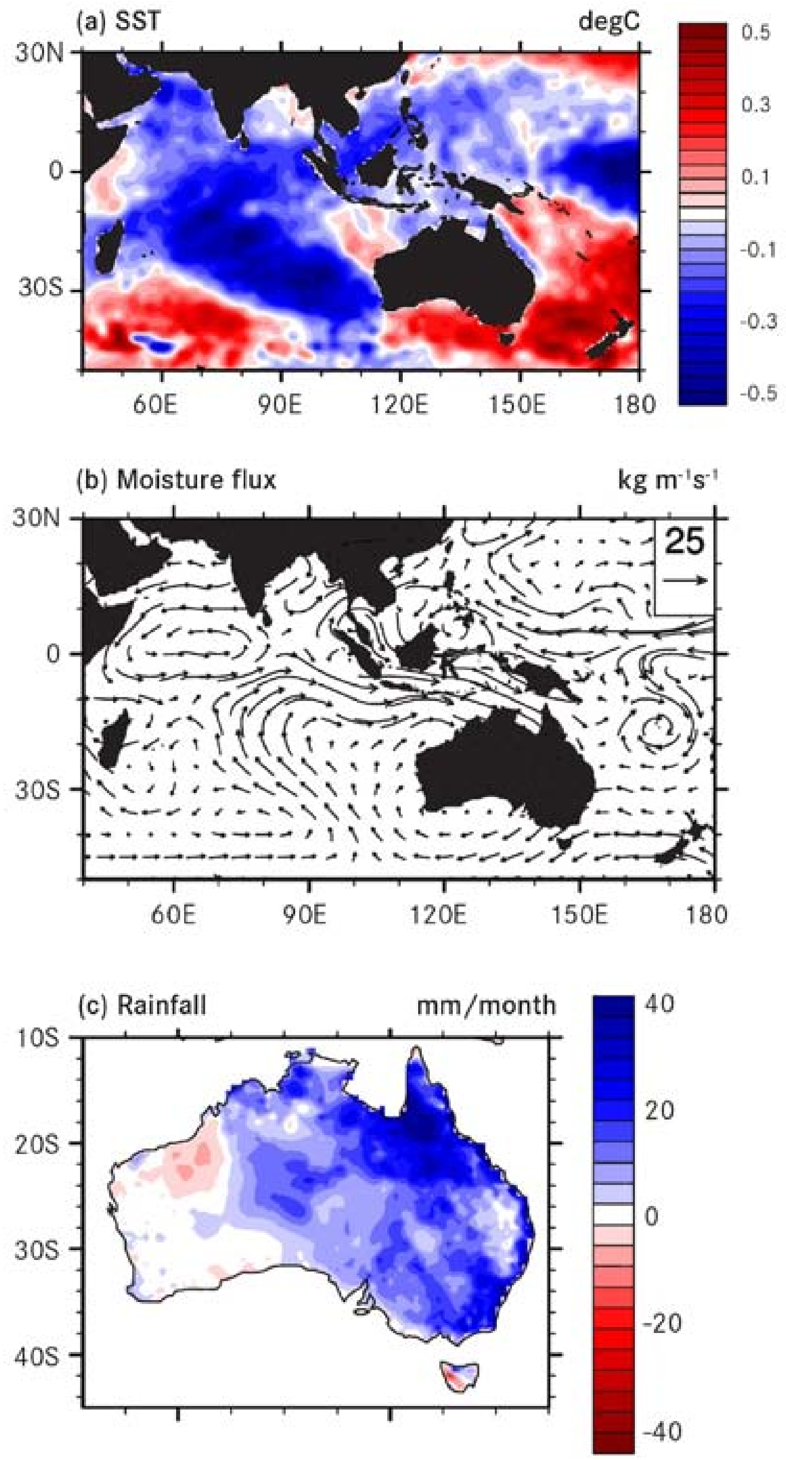
Before trying to crystallise the hotchpotch of meteorological information that is available to predict weather and MVE outbreaks in south-eastern Australia, the present climatic situation in that region must be addressed. As of mid-2009, the drought in the area was still extant. According to the drought update issued by the Murray Darling Basin Authority…"new data revealing inflows to the (Murray) river during the first quarter of 2009 were the lowest since records began 117 years ago"… "with latest forecasts (predicting) lower-than-average rainfall across most of the Murray catchment over the next three months.[8] The Murray Darling Basin and the Murray Valley including its southern tributaries must return to some degree of 'normalcy' before any of the predictive factors that have been discussed can be meaningfully applied. Return of these regions to a normal state like they were, say 15–20 years ago, may not eventuate for reasons such as: the damage to the riverine systems and adjacent wetlands may be irreparable in the short to medium term; progressive global warming; changes in 'water management' along the river systems; and diversions of water from rivers to sustain water supplies to growing cities and towns. Nevertheless, it is inevitable that the Big Dry will break and soaking rains, even floods, will occur in south-eastern Australia. Restoration of the wetlands and their flora and fauna will take time and it may require several seasons of quenching rain before these now arid regions return to their past ecological splendour.

Environmental conditions that favour epidemic MVE in south-eastern Australia have been best documented in the last two outbreaks in 1951 and 1974 (figure 1).[1,3] The terrain was very wet, the Murray River and its northern and southern tributaries were swollen and often flooded; the billabongs and dams were full; low-lying river flats were under water and many surface water collections had formed throughout the region. As summer progressed, expanding pastures led to an incredibly large proliferation of water birds and mosquitoes. The low level of endemic MVEV in south-eastern Australia expanded into the myriads of new mosquito-bird cycles, leading to great amplification of the virus and a very high percentage of infected mosquitoes. It was fortuitous that sub-clinical to clinical rate in humans was so low, because in these circumstances it was almost impossible to avoid mosquito bites. It is apparent, that an enormous volume of water had to enter south-east Australia, by one means or another, to result in this scenario.

The pluvial patterns and their meteorological origins, required to produce such extreme wet weather in south-east Australia are still ill-defined, but some tentative conclusions can be made.

- As evidenced particularly by the 1951 and 1974 MVE epidemics, excess rainfall in the catchments of the northern river systems feeding the Murray Darling Basin is a prerequisite. Although unproven, two successive seasons of excess rainfall in these catchments has theoretical appeal. Rainfall in the first season wets the terrain thus facilitating water flow into the tributaries in the second wet season.
- A La Niña event may predict excess rainfall in the north-east and east of Australia, but it is not a reliable predictor of the same in south-east Australia.
- Floods in Queensland do not guarantee a 'flow on' down into the Murray Darling Basin or beyond. This was exemplified by events in 2008 and 2009 when the Basin was in a dry/arid condition. It seems plausible that the Basin itself must be in a 'wet state' with its rivers flowing, to allow massive volumes of water to flow easily southwards to the Murray River. Two consecutive seasons of average or above-average rainfall in the Basin would optimise this.
- The region south of the Murray River must also receive average or probably higher than average rainfall in the preceding one or two wet seasons. This would be essential if the region has been recently subjected to abnormally low rainfall or drought. Based on the examination of historical data, excessive rainfall has never occurred during a positive phase of the IOD. All previous MVE epidemics have

Figure 1: Climate anomalies leading up to the MVE outbreaks of 1951 and 1974. Shown are anomalies of (a) SST, (b) moisture flux, and (c) rainfall over the region averaged for 1950–1951 and 1973–1974



happened during 'wet' years, as categorised by La Niña and IOD events (figure 1).

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