The rains of February 2004: Forcing from the tropics?

George N. Kiladisa and Michael J. Revellb

\textsuperscript{a}NOAA Aeronomy Laboratory, Boulder, Colorado, United States of America
\textsuperscript{b}National Institute of Water and Atmospheric Research, Wellington, New Zealand

Abstract

February 2004 weather was unusual. Normally a settled period for the North Island of New Zealand, the monthly rainfall for February 2004 was four to six times average from the Waikato down to Wellington and in the Wairarapa. It was also very cold and it was the windiest month over the North Island since monitoring started in 1941, in marked contrast to January 2004.

We show that the change in the tropical mean circulation between January and February 2004 had many features in common with the canonical circulation change associated with the two phases of the Madden Julian Oscillation (MJO). Associated with these tropical changes, through Rossby wave propagation and the setting up of teleconnections, there are also changes in the higher latitude circulation. We show the correlation between these higher latitude circulation changes and the MJO is weaker than that for tropical regions, but nevertheless it is significant.

The low frequency component of a series of synoptic scale rainfall events over 1-2 month periods, such as was observed for instance during February 2004, showed a relatively weak but statistically significant relationship with negative outward longwave radiation (OLR) anomalies over Indoniesia and northern Australia. Lagged relationships confirmed that the tropical convective signal propagated eastward much in the same way as the evolution of OLR within the composite MJO.

\textsuperscript{1}Corresponding author: Dr. M. J. Revell, NIWA Wellington, PO Box 14901, Wellington, New Zealand. Email: m.revell@niwa.co.nz

Corresponding Author address: Dr M.J. Revell, NIWA Wellington, P.O. Box 14901, Wellington, New Zealand.
E-mail: m.revell@niwa.co.nz
1. Introduction
Traditionally, February is a settled month for the North Island of New Zealand - dominated by anticyclones, but with a small risk of a subtropical low bringing heavy rain. It is usually the warmest and driest time of year for many parts of the North Island (Sturman and Tapper, 1996). But February 2004 was different. The monthly rainfall, shown in Fig.1, was four to six times typical February amounts from the Waikato to Wellington and also in the Wairarapa. It was very cold, with record-low February temperatures recorded in some inland and southern parts of the South Island. Consistently strong westerly winds affected the country – according to climate records at NIWA\(^1\) it was the windiest February over the North Island since monitoring started in 1941.

In contrast, January was very warm overall, with above normal temperatures in most regions, especially in the east where it was very warm from Wairarapa to Southland. More frequent easterlies over the North Island and northeasterlies over the South Island meant the East of the North Island was wetter than average and the South Island, particularly in the southeast, was drier than average. Winds were consistently less than normal over the whole country.

The weather during this two-month period was characterized by an abrupt shift in the storm track at the end of January, resulting in a very active string of strong cyclones over New Zealand during February. This shift was accompanied by marked changes in the tropical circulation and an eastward shift in deep convection associated with the Madden-Julian Oscillation (MJO). The MJO is the most important control on intraseasonal convective variability in the tropics, and is well documented in the literature (e.g. Madden and Julian, 1994). While the MJO is known to have a large impact on rainfall over large portions of the tropics, such as the "top end" of Australia (e.g. Wheeler and Hendon 2004; Wheeler and McBride 2004) and the circulation over the Southern Hemisphere on intraseasonal time scales via Rossby wave propagation and tele-connections (e.g. Kiladis and Mo, 1998; Renwick and

\(^1\) NIWA – National Institute of Water and Atmospheric Research
Revell, 1999; Revell et al., 2001), there has been relatively little work on its influence on weather over New Zealand. However, one such example is the study of Zheng and Frederiksen (2004) which looks at the three most dominant intraseasonal coupled modes of interannual variability of New Zealand December, January, February (DJF) surface temperature and 500hPa geopotential height. They show, for example, a clear relationship between the global circulation associated with the MJO and anomalous New Zealand surface temperatures. At the opposite phase to that shown in their Fig. 4(a), the
Southern Hemisphere circulation is remarkably similar to Fig. 2(b) in this paper, and is associated with much cooler conditions over New Zealand.

In this study we consider the transition from benign weather in January to the extreme events of February 2004 in the context of the potential low frequency forcing in the extra-tropics resulting from changes in large-scale tropical convection. We will demonstrate that the evolution of the circulation on the intraseasonal time scale during these months is consistent with the mean signal associated with the MJO, even though February 2004 represents an extreme realization of the typical scenario.

Current general circulation models (GCM’s), particularly those without an interactive ocean component, fail to accurately represent the MJO (Inness and Slingo, 2003). Consequently they fail to produce the appropriate teleconnections in the extra-tropics. With improvement in the representation of the MJO in dynamic models, such tele-connections between the tropics and extratropics hold promise for the improvement of medium range forecasts over New Zealand. In the mean time statistical methods, like the one presented in this paper, can provide some forecast skill in higher latitudes because of the lag between observed forcing in the tropics and the remote Rossby wave response.

In the next section we describe the data and methods used in the study with the results and discussion presented in the following sections.

2. Data and Methodology

An extensively utilized measure of tropical convection is the signal of Outgoing Longwave Radiation (OLR) as measured at the top of the atmosphere by satellite. OLR is significantly lower from the cold tops of tropical convective cloud systems than the surrounding cloud-free areas. We obtained the space-time interpolated OLR data set from the Climate Diagnostics Centre (Liebmann and Smith, 1996) for this purpose, which comes on a 2.5 degree resolution global grid. The NCEP\textsuperscript{1}/NCAR\textsuperscript{2} reanalysis data (Kalnay et al., 1996) are used

\textsuperscript{1} NCEP – National Centers for Environmental Prediction

\textsuperscript{2} NCAR – National Center for Atmospheric Research
to categorize the circulation both during February 2004 and in the historical statistical analysis. We do not expect any sensitivity of our results to the choice of reanalysis data, since large scale, low frequency intraseasonal signals are generally well-captured by both NCEP/NCAR and ECMWF\(^1\) products (see e.g. Renwick, 2004).

For statistical applications, convection associated with the MJO is identified through space-time filtering of OLR as described by Wheeler and Kiladis (1999). This filtering retains fluctuations with periods between 30 and 96 days associated with only eastward propagating OLR from zonal wavenumbers 0 through 9. An index of the MJO is constructed, as in Wheeler and Kiladis (1999), as the time series of space-time filtered OLR at various locations. For the purposes of this study, we used a simple 30-96 day band pass filtering of OLR and reanalysis data, and monthly averages to isolate the behaviour of the large-scale intraseasonal convection and circulation during February 2004.

The statistical association between the MJO and associated intraseasonal circulation is obtained as in Kiladis and Mo (1998), by correlating and regressing parameters such as either NZ wind or NZ rainfall against filtered tropical OLR. This yields the preferred linear relationship between the independent and dependent variables, and enables the statistical significance of the signals to be assessed once autocorrelation characteristics have been taken into account (Livezey and Chen, 1983).

### 3. Results

Fig. 2 shows the monthly mean OLR and 200 hPa circulation for January and February 2004 centred on the tropical Australian sector. In January suppressed convection over Australasia was seen along with large scale cyclonic circulations evident in the subtropics of both hemispheres (in particular in the southern hemisphere at 30S:80E, 45S:140E and 30S:170W). New Zealand lies within a weak anomalous anticyclonic circulation between two cyclones, with centres to its northeast and just west of Tasmania. During January, a

\(^1\) ECMWF – European Centre for Medium Range Weather Forecasts
preponderance of travelling anticyclones kept most of NZ abnormally warm and free of strong winds. Anomalously strong easterlies over the southern North Island and northwesterlies over the south west South Island made these areas wetter than normal with other areas drier.

By contrast the February conditions featured anomalously strong convection over the north of Australia extending northward across Indonesia to the east of the Philippines (Fig. 2b). Generally stronger than normal anticyclonic circulations now extend through the subtropics on both sides of the equator, at the longitude of the main OLR anomaly, and NZ lies under the influence of anomalous southwesterlies with a cyclonic centre located just south of Stewart Island. Strongly enhanced storminess brought record or near-record rainfall over large parts of NZ, especially over the southwestern portion of the North Island. Detailed maps of the OLR signal indicate that the deepest convection during this month was located over the top end of Australia in the region of Darwin (not shown). Based on statistics of space-time filtered OLR from 1979-2002, this is near but somewhat further south than the typical path of the most intense convection during the passage of the MJO in southern summer (Wheeler and Kiladis 1999).

The transition between January and February circulation over the Southern Hemisphere occurred in conjunction with a strong eastward propagating MJO OLR signal. The circulations of Fig. 2 are typical of those associated with the MJO, with anomalous anticyclones flanking the equatorial convective region, and cyclones associated with suppressed convection over the subtropics (e.g. Weickmann 1983; Hendon and Salby, 1994; Kiladis and Mo, 1998). This is illustrated by the statistical result in Fig. 3, which is obtained by regressing OLR and 200 hPa circulation against a daily time series of MJO-filtered OLR at the grid point nearest to Darwin (12.5°S, 130°E) for December-February 1979-2002. (The grid point nearest Darwin was chosen because this
Figure 2. Monthly mean anomalous OLR and 200 hPa circulation from NCEP/NCAR reanalysis for (a) January 2004 and (b) February 2004. Dark (light) shading denotes OLR anomalies less than (greater than) $-16 \text{ W m}^{-2}$ ($+16 \text{ W m}^{-2}$). Streamfunction contour interval is $5 \times 10^5 \text{ m}^2 \text{ s}^{-1}$. The largest vectors are about $20 \text{ m s}^{-1}$.

was where the correlation was highest - at least for precipitation at Auckland.) MJO convection peaking near Darwin favours anomalous anticyclones over the
south of Japan and southwestern Australia, with subtropical troughs flanking the equator near 150°W. An anomalous anticyclone lies to the east of NZ, with a trough just visible in Fig. 3 south of 60°S at the longitude of NZ. Note also that a negative OLR anomaly extends southeastward from the main convective centre to the north of NZ, indicative of the initial stages of enhanced convection within the SPCZ at this phase of the oscillation (Matthews et al., 1999). Lagged relationships (not shown) indicate these circulation anomalies propagate slowly eastward with the convection. There is some evidence of Rossby wave propagation towards NZ, with wave energy dispersing into the Southern Hemisphere extratropics as for the moving source experiment of Renwick and Revell, (1999). In both the mean MJO picture (Fig. 3) and during February 2004

Figure 3. Regressed OLR and 200 hPa circulation from NCEP/NCAR reanalysis associated with a −40 W m⁻² perturbation in MJO-filtered OLR at the 12.5°S, 130°E for December-February 1979/00-2000/01. Dark (light) shading denotes statistically significant OLR anomalies less than (greater than) −10 W m⁻² (+10 W m⁻²). Streamfunction contour interval is 5 x 10⁵ m² s⁻¹. Only statistically significant wind vectors are shown, the largest vectors are about 5 m s⁻¹.
(Fig. 2b) there are several features in common, although there are notable differences as well. In Fig. 2b the placement of the southern Australia anticyclone and the troughs matches closely the composite, although the anomalous cyclone to the south and the accompanying anticyclone east of New Zealand are further north than in the typical MJO. Thus while the events of February 2004 have much in common with the "canonical" MJO, as might be expected individual realizations of "repeatable" atmospheric events will generally differ in details due to other sources of internal variability, adding "noise" to any quantitative connection, no matter how statistically significant.

For example, such a source of internal variability might be the mode first depicted as principal component 2 in Fig. 5 of Kidson (1975), later called the high latitude mode and now more commonly referred to as the Southern Annular Mode (SAM) as in Thompson and Wallace (2000). This SAM variability consists of an irregular oscillation of the peak zonal mean flow in the southern hemisphere between 40S and 60S. According to the Climate Prediction Centre web site\(^1\) the SAM indexes for January and February 2004 were +0.807 and -1.182 respectively. Positive (negative) values imply an anomalous westerly maximum at 60S (40S) and the means and standard deviations of the SAM index for the years 1979 to 2005 are -0.018 and 0.854 for January and -0.013 and 0.860 for February. Thus, for these two months, the SAM would have reinforced the westerly flow modification over New Zealand associated with the MJO anomalies.

As another measure of the potential connection between the tropics and NZ weather, we show an inverse relationship to that in Fig. 3. Fig. 4 shows the linear relationship between 30-96 day rainfall at Auckland and OLR and 200 hPa circulation, using the same sample as was used to produce Fig. 3. This rainfall filtering essentially represents the low frequency component of a series of synoptic scale rainfall events over 1-2 month periods, such as was observed for instance during February 2004. Along with the expected negative OLR signal over the North Island due to an increased presence of cold cloud tops, this picture also shows a relatively weak but statistically significant relationship with negative OLR over Indonesia and northern Australia. Lagged relationships

\(^1\) [http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/](http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/)
Figure 4. Regressed OLR and 200 hPa circulation from NCEP/NCAR reanalysis associated with a 5 mm/day perturbation in 30-96 day filtered precipitation at Auckland for December-February 1979/00 - 2000/01. Dark (light) shading denotes statistically significant OLR anomalies less than (greater than) –10 W m$^{-2}$ (+10 W m$^{-2}$). Streamfunction contour interval is $5 \times 10^5$ m$^2$ s$^{-1}$. Only statistically significant wind vectors are shown, the largest vectors are about 5 m s$^{-1}$.

(not shown) confirm that the tropical convective signal propagates eastward much in the same way as the evolution of OLR within the composite MJO used to produce Fig. 3. Once again this convection is associated with an anticyclone over southern Australia and to the east of NZ, but now there is a strong cyclone over the Tasman Sea - not surprising given that this is a typical synoptic situation associated with heavy rainfall over the North Island (Kidson, 2000). Thus while there indeed appears to be some relationship between Australian monsoon convection and intraseasonal rainfall over NZ on MJO time scales, it is obvious that such connections are intermittent, and may depend on the initial large scale state of the atmosphere.
4. Summary and Discussion

In this paper we have shown that the change in the tropical mean circulation between January and February 2004 had many features in common with the canonical circulation change associated with the two phases of the MJO. Associated with these tropical changes there are also changes in the higher latitude circulation through Rossby wave propagation and the setting up of teleconnections. The correlation between these higher latitude circulation changes and the MJO is weaker than that for tropical regions, but nevertheless it is significant.

The low frequency component of a series of synoptic scale rainfall events over 1-2 month periods, such as was observed for instance during February 2004, showed a relatively weak but statistically significant relationship with negative OLR over Indonesia and northern Australia. Lagged relationships confirmed that the tropical convective signal propagated eastward much in the same way as the evolution of OLR within the composite MJO.

Clearly, remote response to MJO type forcing is only one of the factors affecting weather over New Zealand. There is also, on less than 30 day timescales, convection east of the Philippines during JJA which leads to a large signal of an anticyclone over Australia and eventually a downstream cyclone north and over NZ as shown in Fig. 10d in Kiladis and Weickmann, (1997). There is also the SAM mentioned in the previous section. However, preliminary correlations of other variables like 30-96 day temperature at Auckland with OLR and 200-hPa circulation show a significant but generally small amplitude lagged relationship with the MJO. We are currently repeating these calculations with gridded daily climate data over New Zealand to see if we can improve the power of the MJO to forecast weather variables over NZ on a monthly time scale.

Acknowledgments

We thank Stuart Burgess for providing us with New Zealand weather data from the NIWA climate database. We thank Brett Mullan and Jim Renwick
of NIWA and an anonymous reviewer for helpful contributions to the final manuscript. The New Zealand Foundation for Research Science and Technology funded one of us (MJR) under contract C01X0202 during this study.

References


