Air–Sea Interaction and the Possibility of Long-Range Weather Prediction in the Indonesian Archipelago

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ABSTRACT

Evidence is presented supporting the hypothesis (first expressed over 60 years ago) that interannual fluctuations of early wet season rainfall in the Indonesian Archipelago can be successfully predicted from prior observations of atmospheric pressure anomalies. It is shown that this predictability is related to sea surface temperature anomalies. The postulated mechanism for this predictability is interaction of the atmosphere and ocean leading to a tendency for anomalies in the two media to persist. Experiments to test this postulate are suggested.

1. Introduction

A recent examination of the state of long-range (i.e., greater than one month) weather prediction practice and research (Nicholls, 1980) reached two apparently contradictory conclusions. On the one hand, there are a number of recent research studies which provide evidence of the feasibility of monthly or seasonal forecasts showing considerable skill (e.g., Namias, 1980; Markham and McLain, 1977; Harnack, 1979). On the other hand, examination of published assessments of operational long-range weather predictions suggests that such forecasts show at best only a marginal level of skill. This suggests that long-range prediction may be feasible only for certain select areas, elements and seasons. The Indonesian Archipelago appears to be one such region. This paper examines the evidence for long-range predictability in this region and discusses the possible physical mechanisms involved.

2. Evidence of seasonal predictability in the Indonesian region

Madden (1976) and Madden and Shea (1978), following a suggestion by Leith (1973), estimated the natural variability of monthly mean sea level pressure and temperature for locations in the Northern Hemisphere. The natural variability of monthly means was defined as those interannual fluctuations that can be attributed to the effects of statistical sampling alone. It is the variability resulting from the variance and autocorrelation associated with daily weather fluctuations. Since such daily weather fluctuations are unpredictable beyond a few weeks, then interannual variations arising from sampling of these weather fluctuations must also be unpredictable on a time scale of a season or more. Thus, only where the actual observed variance of monthly means of a parameter is large relative to this natural variability would we expect to find predictable interannual variations.

Madden (1976) and Madden and Shea (1978) estimated the variance (σ_T^2) associated with the natural variability from seasonal spectra of daily values of pressure and temperature. The actual interannual variance of the monthly means (σ_A^2) was also calculated and the ratio σ_A^2/σ_T^2 was tested using an F-test. Where σ_A^2/σ_T^2 did not differ significantly from a value of 1.0, Madden suggested there was little evidence of any low-frequency variability over and above the unpredictable low-frequency extension of daily weather fluctuations. On the other hand, he suggested that where σ_A^2/σ_T^2 did differ significantly from 1.0 there was at least a potential basis for seasonal predictability. Madden (1976) found that monthly-mean sea level pressure showed little evidence of potential predictability between 40 and 60°N but that the likelihood of potential predictability increased both to the north and south of this midlatitude band. Madden and Shea (1978) found greater evidence of potential predictability for temperature as opposed to pressure.

To gain an idea of the potential predictability of interannual variations in the Indonesia–North Australia region the ratio σ_A^2/σ_T^2 has been calculated for temperature and pressure for each month of the year for Darwin (12°S, 131°E). This ratio also has been calculated for Adelaide (35°S, 138°E) to provide a midlatitude comparison. The method used to calculate the ratio was identical to that described by Madden and Shea (1978) except that only five years of data were used to calculate σ_T^2 and 25 years to

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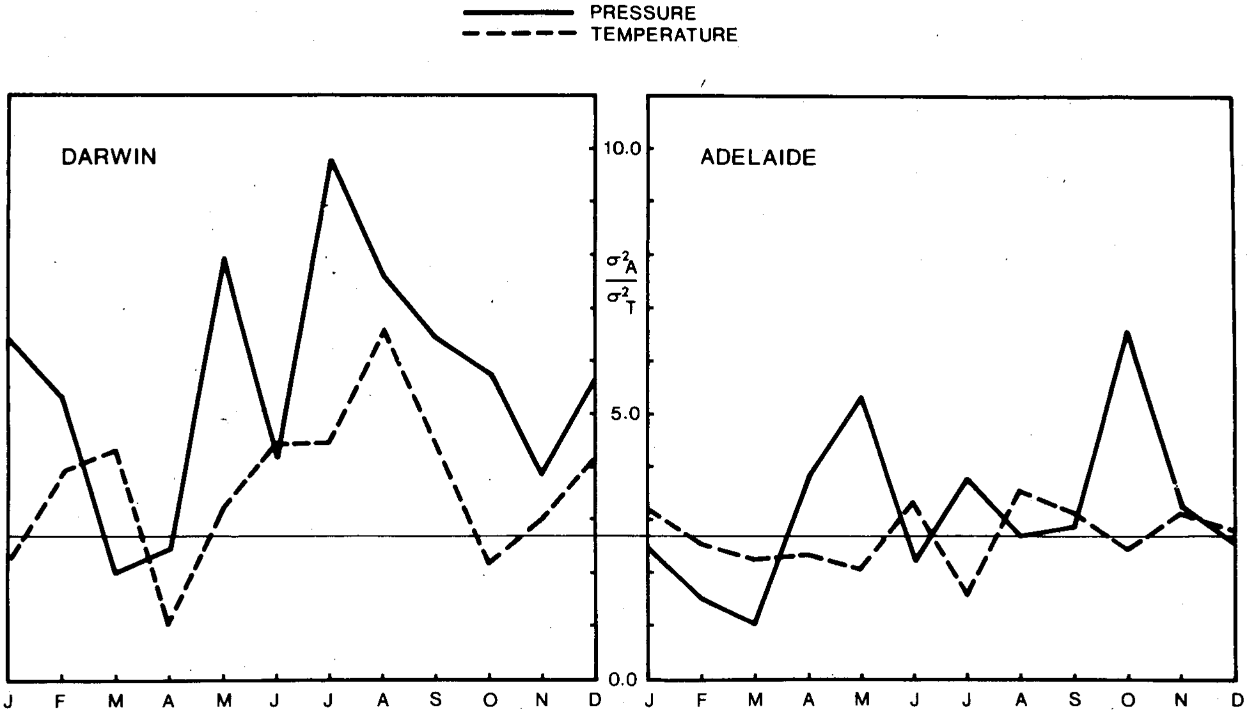

FIG. 1. Values of $\sigma_A{}^2/\sigma_T{}^2$ for Adelaide and Darwin for each month of the year, for surface pressure (full line) and mean daily temperature (broken line). Thin line denotes the 5% significance level. See text for details of calculations.

calculate $\sigma_A{}^2$. This results in changed degrees of freedom for the *F*-test from that used by Madden and Shea (1978). The values of the ratio for each month of the year for monthly means of temperature and pressure are shown in Fig. 1 for the two stations. The 5% significance level is shown as a thin horizontal line. Values of the ratio above this line are significantly different to 1.0, the value expected if all the interannual variations were due to the effects of statistical sampling of daily weather fluctuations, i.e., months with a ratio above the thin horizontal line show evidence of potential predictability. At Adelaide the monthly values fluctuate around the 5% significance level, providing some evidence of potential predictability. At Darwin, however, most of the values easily exceed the 5% significance level, particularly between March and October, providing strong evidence of potential predictability at this time of the year, in that a large portion of the interannual variability clearly does *not* simply arise from statistical sampling of weather variations.

The additional variance which does not result from statistical sampling, although potentially predictable, nevertheless may still be unpredictable in that we may be unable to detect precursors to the interannual climate fluctuations. A number of authors have suggested, however, that such precursors are detectable, at least for the Indonesia–North Australian region.

Over 60 years ago Braak (1919) proposed that Indonesian rainfall during the early part of the wet season (July–December) could be predicted from prior observations of atmospheric pressure in this region. Braak's rule was that if pressure was above average during the first six months of the year, then the quantity of rain during the second six months will be below normal and the rains will start late. Berlage (1927) correlated total September–October rainfall in Java with Darwin average July–August pressure. The correlation coefficient, using data from 1877 to 1926 was −0.63, confirming Braak's suggestion that above-normal pressure was followed by below-normal rainfall. Reesinck (1952), using data from 1916 to 1946, also examined the relationship between the start of the wet season in Java and prior observed pressure over Indonesia and Australia. Once again, Reesinck found strong, highly significant correlations with high pressure signaling a late start to the wet season. Schell (1947) also correlated Darwin winter and spring pressure with Indonesian rainfall in the following months.

A guide to the area covered by this relationship and to the strength of the correlations is shown in Fig. 2a. This figure shows the linear correlation between total station rainfall in September–November with average Darwin pressure in the previous June–August. The correlations for each station are also listed in Table 1. Locations of the stations are shown in Fig. 2c. Data from 1883–1940 (i.e., the data available to Braak, Berlage, Reesinck and Schell) have

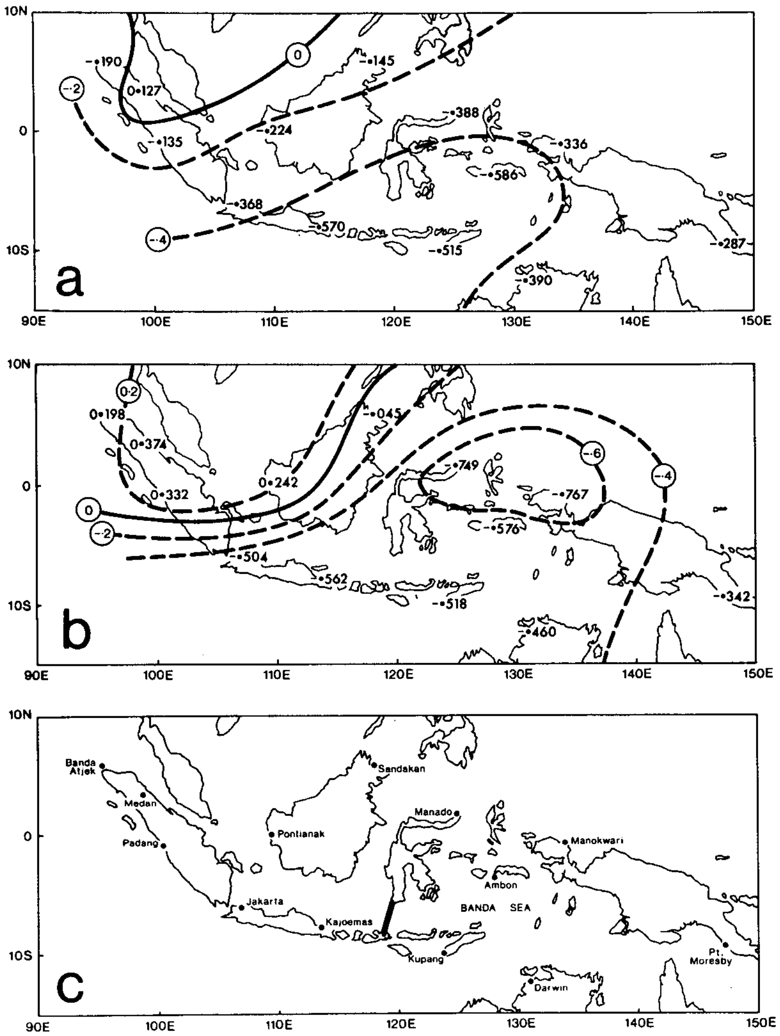

FIG. 2. (a) Correlation between Darwin pressure averaged for June–August and Indonesian September to November rainfall totals. Data from 1883 to 1940. (b) As in (a) except data from 1941 to 1965. (c) Locations of places mentioned in text. The Bima–Makassar streamer route is shown as a heavy line.

been used and the number of years data used for each station varies from 40 to 58. Statistically significant correlations exist over the central and eastern islands of the Indonesian Archipelago and over New Guinea and northern Australia. The correlations of largest magnitude occur around the Banda Sea.

Some of the correlations shown in Fig. 2a and Table 1 are highly significant. For instance, the correlation at Ambon, using 58 years data, was −0.586. The probability of a correlation of such a magnitude arising from chance, rather than being evidence of a real relationship, is <0.00001[1] (using a double-

TABLE 1. Correlations between Darwin June–August average pressure and Indonesian September–November total rainfall. Correlations significant at 5% (1%) underlined once (twice). The numbers in parentheses indicate the number of years of data used in calculating the correlation coefficients.

Station	Long. (E)	Lat.	Correlation coefficients 1883–1940	Correlation coefficients 1941–65
Banda Atjek	95°25′	5°31′N	−0.199 (58)	0.198 (8)
Medan	98°41′	3°34′N	0.127 (58)	0.374 (16)
Padang	100°22′	0°56′S	−0.135 (58)	0.332 (12)
Jakarta	106°50′	6°00′S	−0.368 (58)	−0.504 (24)
Pontionak	109°20′	0°01′S	−0.224 (58)	0.242 (14)
Kajoemas	114°9′	7°56′S	−0.570 (53)	−0.562 (20)
Sandakan	118°7′	5°50′N	−0.145 (48)	−0.045 (10)
Kupang	123°34′	10°10′S	−0.515 (51)	−0.518 (13)
Manado	124°55′	1°32′N	−0.388 (58)	−0.749 (15)
Ambon	128°05′	3°42′S	−0.586 (58)	−0.576 (9)
Darwin	130°52′	12°25′S	−0.390 (58)	−0.460 (26)
Manokwari	134°03	0°53′S	−0.336 (40)	−0.767 (10)
Pt. Moresby	147°13	9°26′S	−0.287 (46)	−0.342 (26)

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[1] Significance levels quoted throughout this paper have been calculated without correction for a possible reduction in the number of degrees of freedom due to serial correlation. Serial correlation, however, is very weak in these series and would not markedly affect the calculated significance levels.

sided t test). There is a 95% chance that the true value of the population correlation coefficient (the −0.586 is a sample coefficient) is between −0.38 and −0.74 (from Pearson and Hartley 1958). The high statistical significance of this and other coefficients in Fig. 2a and Table 1 provides strong evidence for the predictability of interannual variability of September–November rainfall in this area, i.e., the precursor of these interannual variations can be detected.

While the magnitude and statistical significance of the correlations in Fig. 2a and Table 1 provide *prima facie* evidence of seasonal predictability, even stronger evidence is furnished by the results of an independent verification. The correlations between total station rainfall received from September to November, and June to August average pressure at Darwin, have been recalculated using only data from 1941 to 1965, i.e., not using any data available to Braak, Berlage, Reesinck or Schell when they suggested that seasonal rainfall at this time of year was predictable. Data after 1965 were not available for many of the stations and most stations had considerable gaps in the observation record between 1941 and 1965. As a result, some of the correlations have been calculated using less than 10 pairs of data. Nevertheless, there is good agreement between the coefficients in the pre-1940 period and the independent, post-1940 period (Fig. 2 and Table 1). In the later period positive correlations have appeared over Sumatra and the area of negative correlations of greatest magnitude has shifted north. However, the remainder of the pattern of the correlations in Fig. 2b is similar to that in Fig. 2a, with negative correlations over the central and eastern parts of the Archipelago. Of the seven stations with correlations significant at the 5% level (Table 1), five produced statistically significant correlations (of the same sign) on the independent data. The two stations that did not produce significant correlations, Ambon and Kupang, nevertheless showed strong negative correlations of about the same magnitude as in the earlier data set. Overall, Fig. 2b provides an extremely credible verification, on completely independent data, of the suggestions of Braak, Berlage and Reesinck, as represented in Fig. 2a. It is stressed that the probability that the pattern of strong correlation coefficients of Fig. 2a would be essentially reproduced on independent data is extremely slight, unless the relationships shown in Fig. 2 represent a real, continuing physical process.

While the evidence presented so far leaves little doubt about a predictive relationship for seasonal rainfall over Indonesia at the start of the wet season, the question remains as to whether the relationship is strong enough to provide *useful* seasonal predictions. For instance, the correlation at Ambon in Fig. 2a of −0.586 indicates that the regression only accounts for about 34% of the variance of Ambon rainfall, i.e., more than half the variance is not predictable by this relationship. Fig. 3 shows a scatter diagram of Ambon total September–November rainfall versus the average of the Darwin pressure anomalies (from the long-term mean for the month) for the months of June–August. All the available data from 1883–1965 have been plotted. The range of rainfall recorded is very large, from 33 to 1289 mm. Accurate prediction of such a widely varying parameter would presumably be of some value to farmers and government agricultural officials. At first glance the wide scatter of points in Fig. 3 provides little evidence in support of the feasibility of accurate predictions. However, it should be noted that of the 18 years when the Darwin June–August pressure anomaly was above 0.5 mb, on only three occasions did Ambon receive more than 500 mm rainfall in the following September–November period. On the other hand, of the 21 years when the pressure anomaly was below −0.5 mb, only four times was the September–November rainfall *below* 500 mm. Thus, over the period 1887–1965, a forecast that Ambon September–November rainfall would be less (greater) than 500 mm if the Darwin average June–August pressure anomaly was greater than +0.5 mb (less than −0.5 mb) would have been correct 32 times out of 39 forecasts, i.e., 82% of the time. Of possibly more importance is the observation (from Fig. 3) that in none of the 13 years with very low September–November rainfall (<300 mm) was the Darwin June–August average pressure below normal (i.e., a negative anomaly). Thus, the observation of below-average Darwin June–August pressure would enable the issue of a reasonably confident prediction that rainfall in the first few months of the wet season

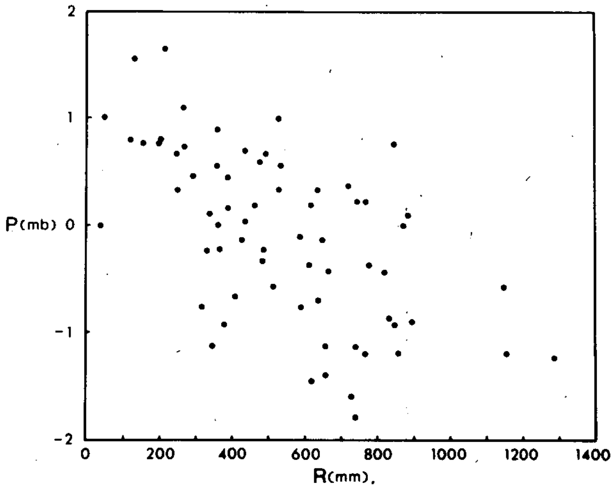

FIG. 3. Scatter diagram of Ambon September to November rainfall totals versus Darwin pressure anomaly averaged from June to August. Data from 1882 to 1965.

would not be extremely low. It is suggested that such a prediction, delivered with such a high expectation of accuracy, would be of some value.

Finally, it is of interest to examine whether some form of averaging of station rainfall might produce stronger relationships, as suggested by Schell (1947). This might be expected, if there is a real physical relationship between pressure and large-scale rainfall in the region, since the occurrence or non-occurrence of a single thunderstorm at a station may have a major effect on the total rainfall received over a period. Since there is an element of chance in whether a thunderstorm will occur either over a station or just a few kilometers away, this element of chance may operate to weaken the evidence of any real large-scale relationship. To test this supposition, rainfalls for each September–November period for each of the seven stations showing a significant correlation in Table 1 were expressed as a percentage of the long-term mean September–November rainfall at that station. Then for each September–November the number (N) of stations recording above average rainfall was determined. This number was then correlated with Darwin June–August pressure. The correlation coefficient calculated from data from 1905–23 and 1931–40 (the only periods for which there exists a complete record for all seven stations) was −0.769. This coefficient is compared in Table 2 with the correlation between Darwin June–August pressure and September–November rainfall at each of the seven individual stations, calculated using the same period of data. As expected, the correlation with N is larger in magnitude than any of the correlations with the single stations, suggesting that the process undertaken in calculating N has filtered out some of the unpredictable noise, thereby allowing the apparent influence of the large scale physical relationship to increase. A scatter diagram of N against Darwin June–August average pressure anomaly is shown in Fig. 4. The closeness of this relationship, as shown by Fig. 4 and the large magnitude of the correlation coefficient, indicates that predictions of spatially averaged rainfall over the Indonesian Archipelago would be even more accurate, and thus potentially more useful, than predictions for single stations (e.g., Ambon; cf. the scatter shown in Figs. 3 and 4). The next section discusses the possible role of air–sea interaction as a cause of this predictability.

TABLE 2. Correlations of Darwin June–August average pressure with Indonesian September–November total station rainfall and with the number (N) of stations recording above-average rainfall. Data from 1905 to 1923 and 1931 to 1940.

Station	Correlation
Jakarta	−0.529
Ambon	−0.714
Kajoemas	−0.678
Menado	−0.492
Manokwari	−0.343
Kupang	−0.610
Darwin	−0.482
N	−0.769

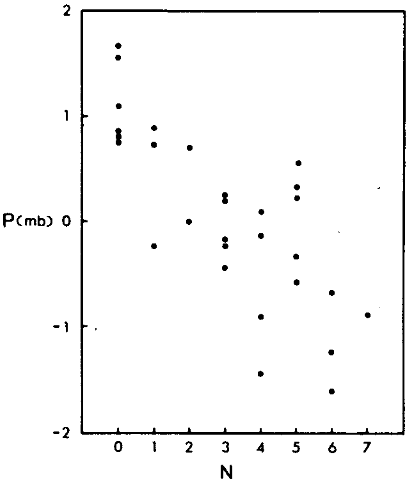

FIG. 4. Scatter diagram of Darwin pressure anomaly averaged from June to August versus the number (N) of stations recording above-average September–November rainfall. Data from 1905 to 1923 and 1931 to 1940.

3. A possible cause of long-range predictability in the Indonesian region

During the past 20 years there has been a substantial growth of empirical evidence to support the hypothesis that anomalies of sea surface temperature (SSTA's) are interconnected with anomalies in the atmospheric general circulation (e.g., Ratcliffe and Murray, 1970; Namias, 1976; Markham and McLain, 1977; Davis, 1978; Horel and Wallace, 1981). The possible effects of SSTA's on the atmosphere have also been studied using linear models (e.g., Webster, 1981; Egger, 1977; Gill, 1980) and general circulation models (for a recent review see Rowntree, 1979). These model experiments have in general supported the proposition that SSTA's have an effect on the general circulation but show the nature and strength of this effect to be highly dependent on the location of the SSTA. A possible explanation of these variations has been offered by Webster (1981).

Some of the above studies have examined the relationship between SSTA's and climate anomalies in terms of a one way interaction—i.e., the SSTA is specified and while the atmosphere is free to respond to this anomaly, there is no feedback of the atmospheric response to the ocean. Others (e.g., Brier, 1978; Nicholls, 1978; Wright, 1979) have emphasized that both the SSTA's and the atmospheric anomalies may arise from a continual two-way interaction between the atmosphere and ocean. For

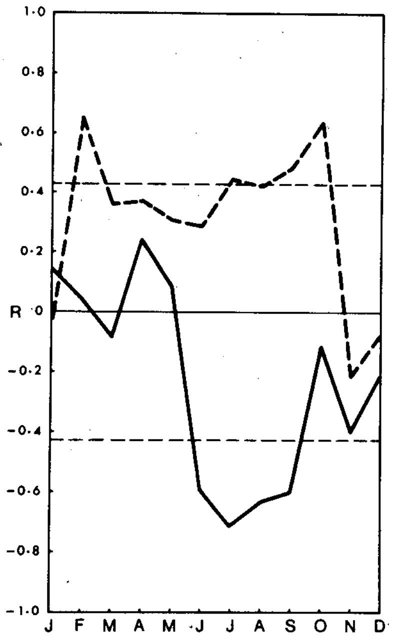

FIG. 5. Correlation of three monthly totals of Jakarta rainfall with sea surface temperature on the Bima–Makassar route (dashed line) and Darwin pressure (solid line) in the previous month. Characters on horizontal axis indicate month of pressure and sea surface temperature observation. Data from 1913 to 1937. Horizontal broken lines denote the 5% significance level (from zero).

instance, Wright (1979) suggested a systematic feedback interaction to explain the persistence of Pacific atmospheric anomalies. It is suggested here that such a systematic feedback is the underlying cause of the predictability of climate anomalies in the Indonesian region discussed above. Evidence supporting the relationship of this predictability to air-sea interaction is now presented along with a discussion of the postulated cause of this interaction.

Long-period records of sea surface temperature in the Indonesia–North Australia region are rare. Probably the best series of observations is that established on the route between Bima (8°S, 119°E) and Makassar (5°S, 119°E) between 1913 and 1937 (Schregardus, 1938). As early as 1927 Berlage established that SSTA's along this route appeared to be related to atmospheric anomalies in the Indonesia–North Australia region. For example, using the data from 1913 to 1937, the correlation between August mean SSTA's, recorded on the Bima–Makassar route between 6 and 7.5°S, and Darwin atmospheric pressure is −0.739, while the correlation between September mean SSTA's and Jakarta rainfall for the same period is 0.781. Furthermore, the SSTA's are also related to future atmospheric behavior: Fig. 5 shows the correlation, for each month of the year, between the monthly mean SSTA and the total rainfall for the following three months at Jakarta. Strong positive correlations, near or above the 5% significance level, occur between February and October. Also shown in Fig. 5 are the correlations between monthly mean Darwin pressure and total Jakarta rainfall in the following three months, again using only the 1913–37 data. These correlations, as expected from the evidence provided in the previous section, are negative and their magnitude exceeds the 5% significance level between June and October. Accordingly, Fig. 5 suggests that either SSTA's or atmospheric pressure could be used to predict Indonesian rainfall during the middle and late parts of the year.

This predictability appears to arise from a tendency for large-scale anomalies in the atmosphere and the ocean to persist for several months at this time of year. Fig. 6 shows the autocorrelations at one month lag of both SST on the Bima–Makassar route and Darwin pressure. Again, only 1913–37 data were used for both variables. These autocorrelations illustrate the strong persistence of the anomalies with some month-to-month correlations exceeding 0.8. One way of explaining this strong persistence in both the atmosphere and the ocean is to propose a positive feedback mechanism whereby an anomaly in, say, the ocean results in an atmospheric anomaly which in turn intensifies or reinforces the initial oceanic anomaly. Nicholls (1979) has suggested that such positive feedback might take place in the Indonesian–North Australia region during winter and spring, leading to strong oceanic and atmospheric persistence. The postulated interaction mechanism is described below. It is suggested that a SSTA located in the Indonesian region induces an anomaly in the lower tropospheric wind flow over the SSTA. The form of the induced atmospheric anomaly is such that, during the Southern Hemisphere winter, it leads to a strengthening of the SSTA which leads, in turn, to a stronger, induced atmospheric anomaly.

This postulated feedback mechanism is perhaps best described using the results of a recent numerical

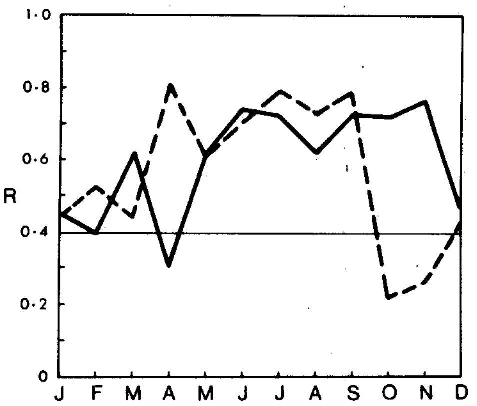

FIG. 6. Autocorrelations, at lag one month, of monthly mean sea surface temperature on Bima–Makassar route (dashed line) and Darwin surface pressure (solid line). Data from 1913 to 1937. Thin line denotes 5% significance level.

experiment on the effect of equatorial SSTA's on the atmosphere (Keshavamurty, 1981). Keshavamurty examined the response of a spectral general circulation model to a warm SSTA located over Indonesia. The model included the annual cycle and the response was studied for the period June–August. In the immediate vicinity of the SSTA, precipitation increased, surface pressure decreased, and at low levels of the atmosphere a westerly wind anomaly was induced. Only over the far eastern portion of the SSTA was the wind anomaly easterly. This result (the anomalous westerlies over most of the SSTA) is similar to that found in linear models (e.g., Egger, 1977; Gill, 1980), and in other general circulation model experiments (Rowntree, 1979), and is the result of the location of the largest induced pressure anomaly being some considerable distance poleward of the warm equatorial SSTA.

In turn, this anomalous wind circulation will affect the SSTA. A brief discussion of the possible effect on the SSTA follows.

The prevailing wind direction over the Indonesian Archipelago in the Southern Hemisphere during winter and spring is easterly. Thus the induced anomalous westerly flow would result in a weakening of the prevailing easterly wind over the SSTA possibly resulting in a decrease in oceanic turbulent transport of heat to deeper water, leading to a warming of the ocean surface. Evaporational cooling, and possibly equatorial upwelling, might also decrease as a result of the decrease in the easterly wind flow. Both these effects, if they took place, would also lead to increases in the sea surface temperature, thus increasing the magnitude of the initial warm SSTA. In turn the increased SSTA would induce a stronger atmospheric response which would again feed back to further increase the SSTA. Thus this postulated positive feedback, which results from the interaction between the atmospheric response to the equatorial SSTA, and the prevailing easterly wind during the Southern Hemisphere winter and spring, would lead to an increase in the magnitude of the SSTA.

If, on the other hand, a cold SSTA was located over the Indonesian Archipelago, one might expect the atmospheric response to be opposite to that induced in numerical models (e.g., Keshavamurty, 1981) by the warm SSTA, i.e., an easterly wind anomaly would be induced over the equatorial SSTA. This anomaly would result in increased easterlies over the SSTA possibly leading to increased turbulent downward heat transport, upwelling and evaporational cooling, all of which would tend to reduce the sea surface temperature even further. Again, this stronger cold SSTA would induce a stronger atmospheric response which would, in turn, reduce the cold SSTA even further.

Thus, whether the initial SSTA was cold or warm, the postulated feedback would tend to cause the magnitude of the SSTA to increase during the Southern Hemisphere winter and spring. The same feedback also would tend to progressively increase the strength of the induced atmospheric anomalies. Thus the positive feedback would act to reduce the likelihood that the SSTA and the atmospheric anomaly might be destroyed by other processes, i.e., it would lead to a tendency for the anomalies to persist. This strong persistence would allow use of atmospheric pressure or the SSTA as a predictor of future atmospheric or oceanic behavior.

It should be noted that the feedback postulated above ignores the possibility of SSTA's arising from advective processes. The likely effect of such advection on SSTA's, with an anomalous equatorial wind circulation, is difficult to assess.

The mechanism proposed above could be tested with a coupled ocean/atmosphere numerical model. If such a model was run for a Southern Hemisphere simulation, a SSTA in the Indonesian region should tend to persist for longer than might otherwise be expected. Wells (1979) has completed such an experiment, but with the SSTA located in the central equatorial Pacific, rather than in Indonesia. However, in the central equatorial Pacific, the prevailing wind also is easterly and so the postulated mechanism also should work here to cause anomalies to persist. The model used by Wells was a nine-level general circulation model of the Southern Hemisphere atmosphere, coupled at each grid point with a one-dimensional mixed-layer ocean model, extending from the ocean surface to a depth of 200 m. Oceanic advection, apart from that associated with Ekman pumping, was not included in the model. Wells ran his model for 80 days and noted that the SSTA persisted with little change throughout this period, although a slight westward movement of the anomaly was observed. The atmospheric anomaly associated with the SSTA also persisted. Thus the result of Wells' experiment tends to confirm the above suggestion of a positive ocean/atmosphere feedback as an explanation of the observed persistence of anomalies in the Indonesia–North Australia region. However, more convincing evidence could be produced by a replication of Wells' experiment with a model capable of simulating large-scale oceanic advection and with the SSTA located over Indonesia, and by a comparison of the result of this experiment with a Southern Hemisphere summer simulation. The prevailing wind over Indonesia during summer is westerly and thus should lead, as discussed in Nicholls (1979), to negative feedback between the ocean and atmosphere. Thus the SSTA in the summer simulation should, if the postulated mechanism is accurate, show a greater tendency to weaken and disappear than the SSTA in the winter simulation.

However, development of a combined ocean/atmosphere general circulation model capable of representing the oceanography of the Indonesian area in sufficient detail (and including large-scale oceanic advection) is probably a long way off. Such a model, rather than that used by Wells (which ignored large-scale advection), is probably necessary to confirm whether the postulated mechanism is responsible for the observed persistence of SSTA and atmospheric anomalies in the Australian–Indonesian region during the Southern Hemisphere winter and spring.

4. Conclusions

Evidence in support of the predictability of early wet-season rainfall in the Indonesian region has been presented and a mechanism for this predictability suggested along with a proposed experiment to test the postulate. The evidence of the feasibility of the routine production of accurate seasonal forecasts of early wet season rainfall rests mainly on the remarkable similarity between correlations calculated on data from before 1940 and the correlations calculated in a completely independent period (Table 1 and Fig. 2). The possibility that this similarity might arise from chance, rather than representing a real physical process is extremely low. Thus a strong case exists for the predictability of early wet season rainfall. The period of predictability (June–November) closely matches the period when the potential predictability (as defined by Madden) of atmospheric fluctuations appears to be at its greatest.

It has also been shown (Fig. 5) that this predictability is related to the behavior of the ocean and it has been suggested (following Nicholls, 1979) that ocean/atmosphere interaction results in positive feedback causing an initial SSTA to persist or even grow in magnitude during the Southern Hemisphere winter and spring. This results in the atmospheric and oceanic anomalies tending to persist. It is this persistence which allows the successful prediction of early wet season rainfall.

Finally, it was suggested that the postulated mechanism could be tested with the use of a coupled ocean/atmosphere numerical model. A SSTA in the Indonesian region should, if the postulated mechanism does take place, persist during a winter simulation. On the other hand, a SSTA in this region should not persist so strongly during a summer simulation. If such effects are not observed in the numerical experiments, we will need to look elsewhere for the physical mechanism underlying the undoubted seasonal predictability in this area.

The mechanism proposed here as a possible explanation of the observed seasonal predictability is a simple one. It is not suggested, however, that this postulated mechanism is the only process operating to determine the nature and behavior of climate anomalies in the Indonesia–North Australia region. On the contrary, the proposed mechanism is seen as just one of the many processes which affect the climate on the time scale of seasons and years. However, it is suggested that the proposed mechanism may play a role in causing an important part of the behavior of climate anomalies in this region, namely, the observed tendency for such anomalies to "lock-in" during the Southern Hemisphere winter and spring. Other mechanisms are seen as potentially complicating this tendency for "locking-in" and persistence of anomalies. This is not to deny their existence but rather to suggest that they may be of secondary importance, relative to the process causing the strong persistence of anomalies. A complete description of the behavior of climate anomalies in this region would require identification and understanding of all these many processes, a somewhat forbidding task.

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