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ORIGINAL ARTICLE

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Domestic Violence in a subtropical environment: police calls and weather in Brisbane

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Abstract Possible relationships between weather and telephone calls to police' complaining of domestic violence, were investigated for Brisbane during 1992. Having accounted for the effect of the day of the week, significant associations were observed between calls and maximum air temperature, during all seasons. Prediction equations have been established for different days of the week. At the weekly level, the temperature association was enhanced by barometric pressure, yielding a regression which explained nearly 50% of the overall variability. It is suggested that the inputs into these regressions can be adequately forecasted, and that appropriate procedures may be developed for their practical application.

Key words Police calls · Weather associations · Forecasting

Introduction

Differences between aggression and geographical location have been largely explained by sociodemographic variables (Rotton 1993), but, in general a linear association has been observed between seasonal warmth and violence by many authors (e.g. Anderson 1987, 1989; Haertzen et al. 1993; Michael and Zumpe 1983a, b; Mitchell 1991; Perry and Simpson 1987; Rotton and Frey 1985). For time periods shorter than seasons, some debate exists concerning the theoretical shape of the response curve and the possible existence of an eventual decline of violence at extremely high temperatures (Anderson and DeNeve 1992; Bell 1992). However, there is consistency within the associations between elevated warmth and sexual aggression (Michael and Zumpe 1983a, b; de Fronzo 1984; Perry and Simpson 1987; Cohn 1993) and domestic violence (Cohn 1993; Mitchell 1991; Rotton and Frey 1985). At least implicitly, the relationship has been seen as a direct response to heat stress.

On the synoptic scale, however, associations also have been sought beyond the purely thermal ones. A variety of weather parameters have been included in studies of daily observations, including light, fog, and wind by Cohn (1993); humidity, barometric pressure, and oxidants and light by Rotton (1993). The findings of LeBeau and Corcoran (1990) have indicated that aggression as measured by calls for the police service can be related to the passage of warm and cold fronts over Chicago, with a decreased rate of calls during the cold-associated events.

In police work in particular, the potential application of the dominant thermal association has been suggested by LeBeau and Corcoran (1990), Mitchell (1991), and J.L. LeBeau (personal communication). Several practical issues arise if, for particular locations, strong associations can be established. If weather, and especially levels of ambient warmth can be effectively forecasted, there may be useful adjustment that can be made by crime prevention authorities, or even the victims themselves. The present study aimed to test the strength of forecastable parameter associations with domestic violence calls to the police in subtropical Brisbane, and to preliminarily, suggest steps that need to be taken to establish an applicable system of forecasting methodology.

Methods

The incidence of domestic violence in Brisbane during the calendar year 1992 was represented by the number of telephone calls received at police headquarters for help and appropriate seeking of assistance. These calls were logged by the police by date and time of day, but since the association was investigated daily, the particular period of the diurnal cycle at which these occurred was not considered.

For a coastal and hilly city of a million people living on an area about 1000 km^2, it was recognised that no single measurement fully represents the existing atmospheric environment for all locations. However, the error introduced was not considered to be sys-

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tematic with respect to the location of calls, and the error at this aggregate level of analysis was only likely to reduce the degree of any association. Given that coastal locations often experience a temperature amelioration of 5° C both in summer and winter, and that rainfall and wind velocities are effectively halved in the inland locations (the "western suburbs") as opposed to the coastal locations, any association that emerges can be considered a significant underestimation.

Accepting these constraints of data variability, the regular recordings by the Australian Bureau of Meteorology at Brisbane Airport, located some 10 km seawards from the city centre, were assumed to give at least a first order representation of the atmospheric environment for these calls. A database was established from the frequency of calls (CALLS), date, identifiers for public and school holidays, the day of the week, incidence of full moon and common atmospheric parameters such as Celsius temperature maximum (T_{max}), minimum (T_{min}), and the mean of the two (T_{mean}) – the daily mean temperature, the 1500 hours dry bulb air temperature (T_{db}), barometric pressure in hectoPascals ×10 (Pr), wet bulb temperature (T_{wb}), the percentage relative humidity (RH), windspeed in km/hr (WV), visibility in decametres (Vis), total (C_T) and low cloud (C_l) in tenths, and the amount of rainfall in mm (RAIN) for the preceding 24 h.

Several derived atmospheric parameters were also calculated, including the temperature-humidity discomfort index commonly used in USA (Thom 1957), as also used earlier by J.L. LeBeau (personal communication). Several estimates of this were made, including the deviation from an assumed thermally neutral value at 70° C (THI), there being no particular reason to convert for the present purposes from values normally based on the Fahrenheit scale. The other derived warmth variable T_{acclim} was a deviation of T_{max}, not from a set constant as in THI, but from the empirically observed preferred temperature, as reduced by 0.31° C for every degree difference in mean monthly values (Auliciems 1983). This was thought to be necessary to allow for the expectation of a decreased effect of heat in the latter half of the summer due to warmth acclimatisation in late September–November. At this time before the acclimatisation process is complete, proportionally greater stress could be expected to occur.

Visual inspection of the distributions of the calls and the parameters using several time filters appeared to indicate that calls in general increased with the incidence of rain, except that with extreme values there appeared to be a suppression in the number of calls. Therefore a further variable in $RAIN^2$ was generated and included in all subsequent analyses. Eventually, as discussed in the Results under Weekly association, a quadratic expression was also generated for pressure values.

A number of preliminary statistical procedures were applied to analyse possible relationships for the phases of the moon and holidays, including both public and school holidays. No obvious relationships could be identified with calls and only the day of week and weather variables were retained for fur-ther analysis. Table 1summarises these data for the year. Clearly the day of the week largely determines the frequency of the calls, with most being during the weekend. To remove this effect, calls were converted to Z-scores for day of the week (CALLS-*z*). That is, the scores were standardised in the usual way with respect to the different means and standard deviations in Table 1 by expressing each value as a deviation from the mean number of calls for particular days as divided by their standard deviations.

Table 1 Summary of data for 1992

Variable	Mean	SD	Range
CALLS			
Monday	4.69	2.47	1–11
Tuesday	4.96	1.95	1–9
Wednesday	5.51	3.25	1–17
Thursday	5.81	2.43	1–10
Friday	6.11	3.06	2–18
Saturday	8.64	2.71	4–16
Sunday	8.64	2.92	3–15
T_{max} (° C)	25.09	3.52	16.1–34.8
T_{min} (° C)	15.32	5.20	3.4–25.2
T_{acclim} (° C)	25.03	5.50	19.0–32.5
THI (° F)	2.54	5.24	9.2–14.0
T_{db} (° C)	23.70	3.62	33.5–14.1
T_{wb}(° C)	18.00	3.89	26.6–10.4
Pr (hPa)	1013.92	5.67	998–1028
RH (%)	55.4	16.5	11–98
RAIN (mm/day)	3.48	12.93	0–119.6
WV (km/h)	20.11	7.36	0–43
VIS (dm)	3272.40	877.29	300–5000
C_T (tenths)	3.61	2.64	0–8
C_l (tenths)	1.48	1.10	0–6

Abbreviations: temperature maximum (T_{max}), minimum (T_{min}), average (T_{mean}), 1500 hours dry bulb (T_{db}), wet bulb temperature(T_{wb}), barometric pressure (Pr), relative humidity (RH), windspeed (WV), visibility (Vis), total cloud (C_T), low cloud (C_l), rainfall (RAIN), deviation of temperature-humidity discomfort index from 70° F (THI), acclimatization temperature (T_{acclim})

Results and discussion

Aggregated data and seasonal association

The annual record of T_{max} Z-scores is shown in Fig. 1, together with the CALLS-*z* trace, but to avoid confusion with daily variability, both sets of data are displayed as moving averages for periods of 60 days over the year. In general, there was a decrease in CALLS-*z* with the coming of the cool season, and minimum values coincide with minimum temperatures. With the gradual return of warmer conditions, the CALLS-*z* trace tends to follow the trend of T_{max}. There is an upwards blip in CALLS-*z* following the 60-day period ending in mid-November (as indicated by the arrow in Fig. 1), and when T_{max} begins to exceed 25° C (i.e. a Z-score of about –0.025). This would appear to indicate the enhanced effects of heat stress, and perhaps a violence temperature threshold. It is important to note that this particular temperature is acknowledged by proponents of both the thermal adaptation and constancy hypotheses, as that marking the pivotal point for onset of heat or cold adaptation, as well as the comfort neutral point for unacclimatised populations (see Auliciems 1983; de Dear 1993).

On an annual basis, the overall correlation between the variables using the 60-day filter is r=0.842 for CALLS-*z* vs T_{max}, and r=0.933 for the 60-day block preceding the mid-November T_{max} of 25° C. Beyond this aggregated inspection, analysis was conducted at several temporal resolutions; several filters were subsequently applied, and especially in anticipation of practical applications to police manpower management, particular attention was paid to the maximum possible synoptic prognosis period of about a week. With this particular filter, it was also possible to eliminate the day of week variable and the use of cumbersome individual day of the week Z-scores.

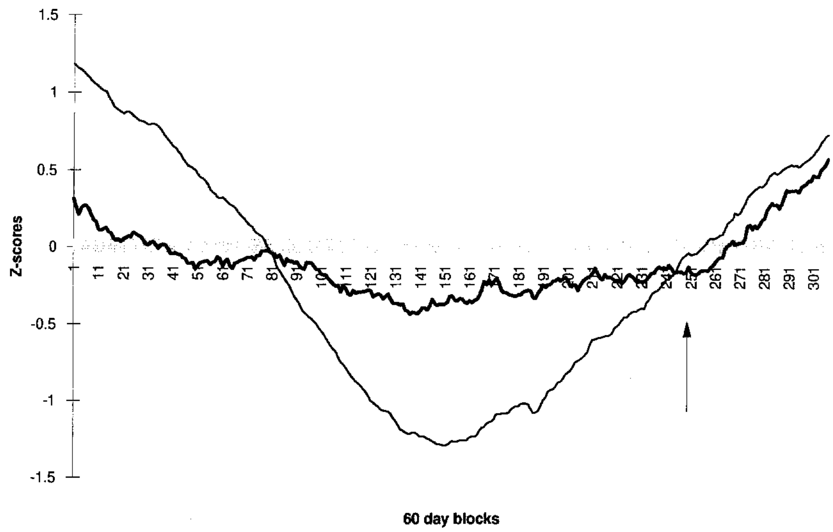

Fig. 1 Daily *Z*-scores of police calls and maximum temperature plotted as moving mean averages of 60-day blocks over the year. *Arrow* indicates the middle of November. ▬ Calls; — max temp

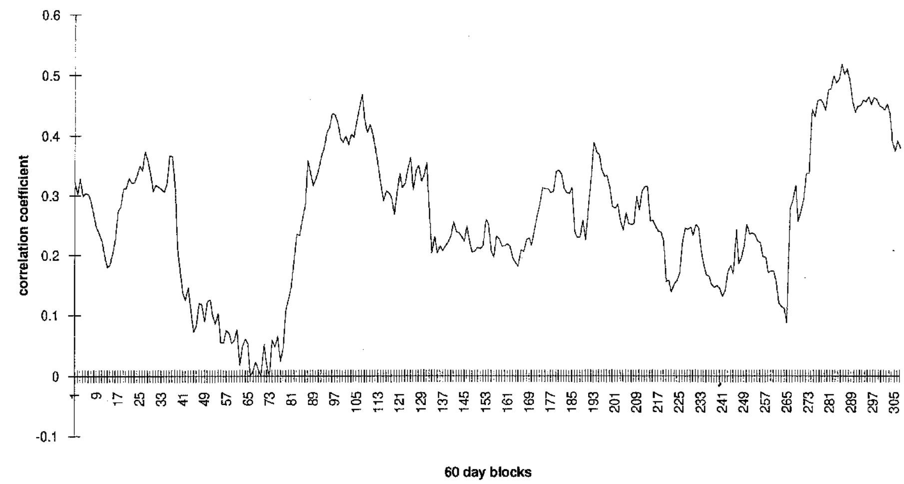

Fig. 2 Correlation coefficient trace for daily police calls against maximum temperature in 60-day blocks

Table 2 Correlation between Z-scores of CALLS (CALLS-*z*) and atmospheric parameters

	T_{max}	T_{min}	T_{mean}	T_{acclim}	T_{db}	T_{wb}	Pr	VIS	C_T	C_l	RH	RAIN	$RAIN^2$	WV	THI
CALLS-*z*	0.364	0.195	0.225	0.291	0.340	0.302	−0.247	0.052	−0.054	−0.005	0.031	0.002	0.008	0.120	0.290

Abbreviations are as defined in Table 1

Daily association

Correlations between the *Z*-scores and daily atmospheric parameters are shown in Table 2. To investigate whether these correlations merely represented seasonal distributions, and to inspect their stability over time, CALLS-*z* were correlated with maximum temperatures in continuous blocks of 60 days (i.e. the first coefficient represented the correlation for January–February and so on). The correlation trace thus produced appears in Fig. 2. Of all the temperatures tested, of the 306 total correlations, only one or two appeared as negative. Therefore the one-tail significance test was deemed as appropriate, being less than 0.01 at r=0.2. At no time did the other temperatures exceed those of T_{max}, nor did further analyses of variance show a significant reduction in the residual sums of squares (RSS) by any of the other atmospheric variables.

Clearly, the temperature-calls association is one that is not a simple summer:winter phenomenon. The finding that the association is not closer for T_{acclim} and THI than T_{max} is a surprise: despite the increase in calls, particularly during the approaching warm season, the association with T_{max} was strong even during the coldest months below thermal neutrality when increased T_{max} values could have been expected to be beneficial rather than detrimental to passive behaviour. It is suggested that, despite the acceleration in the moving mean CALLS trace at 25° C as discussed earlier, the frequency of calls may not be only a function of simple responses to heat stress. Other possible reasons may be sought in more esoteric physiological functions, or in terms of weather perception and psychological responses. For example, it may be hypothesised that the causal relationship is of frustration. The source of this frustration may have been subjective perceptions of loss of opportunity for activities away

Table 3 Statistics for daily regressions of CALLS on daily maximum temperature (T_{max}) of the form CALLS=$aT_{max}+c$

Day	Coefficient a	Constant c	TSS	RSS	t	F	r
Monday	0.145	1.056	317.077	303.496	1.496	2.237	0.207
Tuesday	0.160	0.904	197.923	181.664	2.115	4.475	0.287
Wednesday	0.492	−6.800	561.246	394.592	4.614	21.570	0.545
Thursday	0.213	0.536	314.113	281.803	2.418	5.848	0.321
Friday	0.346	−2.611	487.308	421.361	2.797	7.825	0.368
Saturday	0.334	−0.376	381.923	311.638	3.358	11.277	0.429
Sunday	0.340	0.132	442.058	364.118	3.271	10.702	0.420

TSS Total sum of squares, RSS residual sum of squares, t Student's t-test, F F-ratio, r simple correlation coefficient

Table 4 Significant and near significant correlation of weekly calls (CALLS-w) with weather variables[a]

	Tw_{max}	Tw_{min}	Tw_{mean}	Tw_{acclim}	Tw_{db}	Tw_{wb}	Prw	VISw	Cw_T	Cw_l	RHw	RAINw	RAINw^2	WVw	THIw
CALLS-w	0.659	0.546	0.592	0.415	0.642	0.589	−0.569	−0.179	0.090	0.196	0.200	0.546	0.065	0.321	0.601

[a] Abbreviations as for daily parameters (Table 1) but with additional w suffix

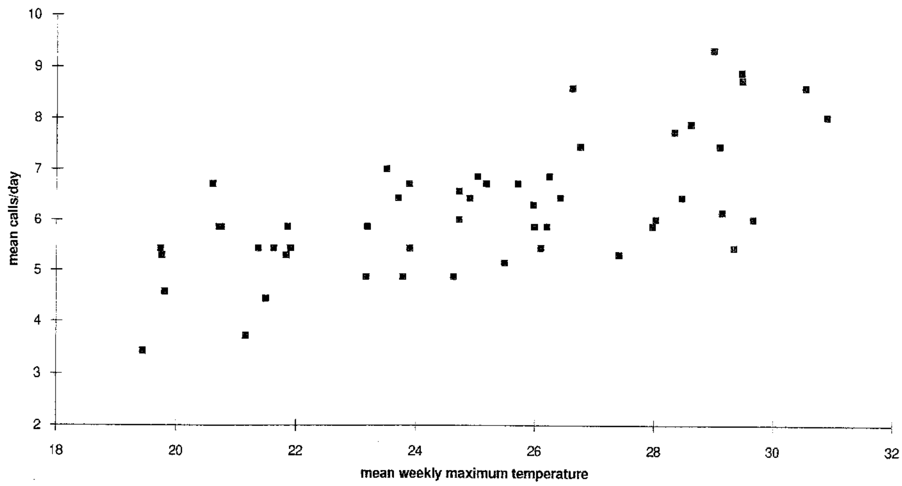

Fig. 3 Daily number of police calls against mean weekly maximum temperature

from home during weather that may have appeared to be optimal not just for routine domesticity.

Nevertheless, the regression allows a prediction of the frequency of calls as follows:

$$\text{CALLS-}z=0.102\ T_{max}-2.548 \quad (1)$$

where F=53.77, residual mean square (RMS)=659, r=0.364, P<0.001.

The predicted values of CALLS could be reconstituted for each day of the week from Eq. 1, and from the means and standard deviations in Table 1. Alternatively, if a temperature association exists, since the call rate increases during weekends, it could be argued that they would do so differentially, with increased "sensitivity" during those times.

To test this, the data were disaggregated for individual days of the week, and the analysis repeated as for the whole data set. Again, the only significant variables were the temperatures, and invariably T_{max} was the most significant. The results of this reanalysis are set out in Table 3 in terms of regression coefficients, analysis of variance, F and t-values, and the correlation coefficient. There is consistency across the calls: temperature regressions. In each the regression coefficient is positive, and both t-values and F-ratios are significant, or near significant, at P <0.01 on all days except Mondays.

Weekly association

Unfortunately there is no convenient way of obtaining and reconverting Z-scores for combinations of individual days, and only the weekly interval allows ready comparison. Significant and near significant correlations were observed between weekly calls (CALLS-w) and weekly Z-scores (all weekly values are designated by the suffix w) of all the temperature expressions as well as the previously used WV, Pr, and RAIN (see Table 4).
The distribution of CALLS-w against Tw_{max} is shown in Fig. 3. Stepwise and all possible regression procedures were applied to the Z-scores for all, and the analysis of variance was inspected for reduction in the total sum of squares (TSS), and significance of the F-ratio for the regressions as well as individual variable t-values. Beyond the single variable regression, Tw_{max} and Prw combined both showed significant individual t-values (see Eq. 2), that is they could be regarded as independent variables for the present purposes). The correlation with pressure, however, seemed to suggest a non-linear association, and all combinations and interactions of the quadratic functions of both Tw_{max} and Prw were calculated.

Standardised scores were used, as calculated from weekly observations and the weekly means and standard deviations [weekly mean Tw_{max} 25.066 (SD=3.202)° C;

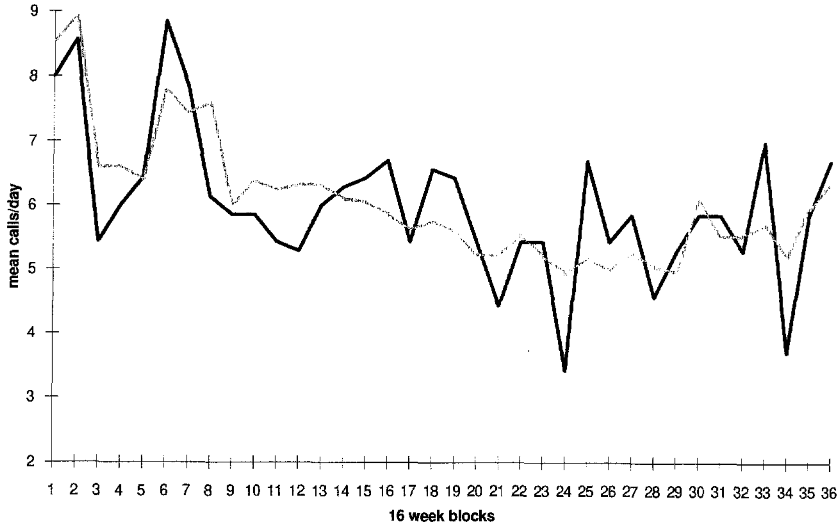

Fig. 4 Observed values of daily police calls and those predicted from equation 2 in text plotted in 16 week blocks over the period of the study ▬ observed; ▬ predicted

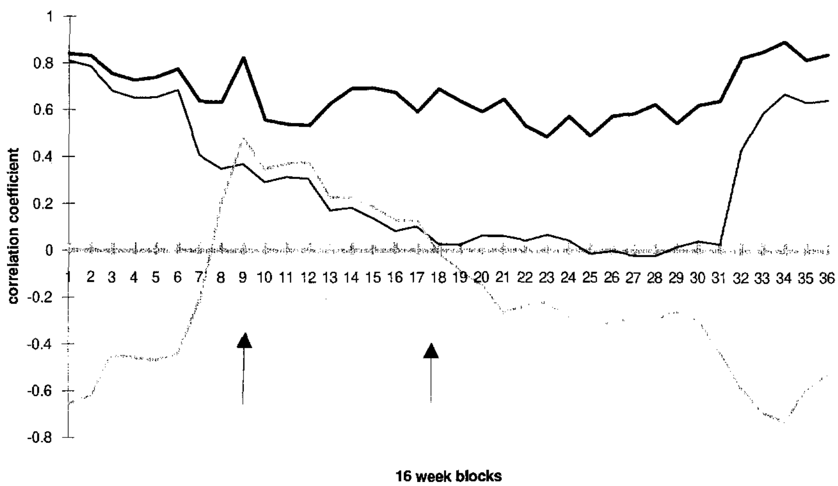

Fig. 5 Correlation coefficients for relationships of weekly police calls with variables from equation 2 in text. *Left arrow* indicates the end of June, *right arrow* indicates end of August. ▬ Multiple; —— max temp.; —— pressure

weekly mean Pr*w* 1013.924 (SD 4.538) hPa]. The statistics generated the best possible combination of the variables Tw_{max}, Pr*w* and Prw^2, where all three variables were significant both by analysis of variance and *t*-tests, and the final model was accepted as

$$\text{CALLS-}w=0.549\ Tw_{max}-0.350\ \text{Pr}w+0.304\ \text{Pr}w^2-5.917$$

$$[3.857, P<0.001]\ [-2.468, P<0.02]\ [3.857, P<0.01] \quad (2)$$

where the simultaneous *t*-values for the weather variables are shown in square brackets together with their two-tailed significance beneath the regression line: for Eq. 2 as a whole F=29.96, RMS=0.849, R=0.761, P<0.001. The goodness-of-fit of predicted to observed values is shown in Fig. 4. Further inclusions of other variables indicated that the parameters RAIN*w*+RAINw^2 [weekly mean RAIN*w* 3.450 (SD 5.907) mm] were also near significant, although the reduction of RSS was only marginal (see Table 5 for comparative statistics).

To check for the stability of the regression (Eq. 2), a running correlation trace was applied using continuous blocks of 16 weeks. The traces for Tw_{max}+Pr*w*+Prw^2, Tw_{max} and Pr*w* are shown in Fig. 5 (the first values are those for January–April). The Tw_{max} correlation trace is positive throughout the year, but the dominant influence until about June (the endings of June and August are indicated by the arrows in Fig. 5) is pressure; thereafter the association is primarily of temperature. It is of interest to note that in the first half of the year, the association with pressure is a negative one, which switches to positive during June–August, and then back to negative in September until the end of the year. That is, when Tw_{max} falls below 25° C, increased weekly calls appear to be related to high pressure systems, while during the warmest months increased calls appear to occur during weeks dominated by low pressure systems. This also appears to be consistent with the rain variable associations. The

Table 5 Multiple regression of weekly calls on weather variables (TSS=82.08)

Variable combinations	RSS	*F*	*R*
1. Tw_{max}	46.46	38.33	0.659
2. Tw_{max}+P*w*	41.33	24.16	0.705
3. Tw_{max}+Pr*w*+RAIN*w*	40.95	16.07	0.708
4. Tw_{max}+Pr*w*+Prw^2	34.59	21.96	0.761
5. Tw_{max}+Pr*w*+Prw^2+RAIN*w*	33.88	16.71	0.766
6. Tw_{max}+Pr*w*+Prw^2+RAINw^2	32.17	18.22	0.780
7. Tw_{max}+Pr*w*+Prw^2+RAIN*w*+RAINw^2	31.04	15.12	0.788

causality for these associations is far from clear, but it seems that calls increase in number during unsettled hot summer weather and calm warm winter weather.

Approaches to forecasting

Since weather processes vary by latitude and location, the practical predictability and applications of observable weather-behaviour associations will need to be individually modelled. Nowadays, the timing and strength of the passage of mid-latitude fronts probably can be forecasted with more than 70% accuracy at many locations for intervals of some 4 to 5 days ahead. In sub-tropical Brisbane (latitude 27° S, eastern continental seaboard of Australia), however, warm fronts do not occur with cold fronts being relatively rare and then only during the winter period. For this area, forecasting would need to rely on other than frontal phenomena.

From the observed relationships, there are a number of approaches that could be taken towards practical applications. The forecasting from weather parameters could be either via weather typing for the site (e.g. Stone 1989), or more directly, solutions to the daily equations 1, 2 and those in Table 3 can be produced from T_{max} forecasts as available from the Australian Bureau of Meteorology. That is, such forecasts could be used to predict 5% of the variability on individual Mondays and Tuesdays, 15% during the weekends, and up to 25% on Wednesdays. Perhaps more usefully, suitable solutions could also be made for the weekly equation 2. That is, from this regression, depending upon the accuracy of forecasts, it would seem that up to half the variation in weekly calls are predictable. This may be enough to enable significant manpower scheduling or response adjustments by the police force.

As could be expected, temperature and pressure-precipitation forecasts will decrease in accuracy the further they look ahead, and forecasts would need to be qualified by indices of reliability, which are likely to vary seasonally and according to particular weather systems. Alternatively the predicted calls could be presented as probabilities with increasing tolerance levels. In either case, the production of such forecasts, and establishment of their levels of uncertainty is no longer a question of a necessary breakthrough in atmospheric science, but one of design to suit the requirements of users. The next stage is to check the model with data for other years, test the reliability of forecasts using independent forecast and calls values, e.g. for 1993. In collaboration with the authorities it would be possible to design and test suitable conditions of temperature and precipitation, and establish appropriate means of communications to law agencies, and also possibly the public. Finally, the practicability of such forecasts needs to be tested over several years.

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