A statistically based approach to nowcasting (0 - 24 hours) on the mesoscale

Harvey Stern, Victorian Regional Office

1. Introduction.

Stern (1996) describes a number of systems of forecast guidance that operate by relating the weather observed at one or more locations (which have extended periods of record) to that weather observed at other locations with shorter periods of record (or no record at all). By this means one may create artificial forecast data for any specific location or to assist with analysis across a region without data. The purpose of this paper is to present a brief summary of that work.

In some cases the methodology employed stratifies the data synoptically and seasonally (Stern, 1980; Stern *et al.*, 1985). In other cases the methodology employed stratifies the data seasonally (Dahni, 1988; Dahni and Stern, 1995). In another case, the data is not stratified at all (Stern, 1994 a&b).

2. Creating "artificial" historical synoptic data.

A number of major projects are currently underway overseas to extend synoptic data backwards in time across areas where little "hard" historical data exists. This is being done by "running" global NWP in reverse four dimensional assimilation modes so that "known" outcomes are used as the basis for determining what synoptic patterns prevailed over the data sparse areas (Kistler *et al.*, 1994; Kingtse and Wang, 1994; Jenne, 1994; Janowiak *et al.*, 1994; and, Gibson *et al.*, 1994).

Alternatively, Annette (1980) suggested that objective historical analysis may be achieved over data sparse areas via statistical means. Annette's (1980) approach is described in detail by Stern (1996).

3. Example.

The procedure that is proposed to derive forecast guidance is now illustrated with the simple example of utilising the physical relationship between maximum temperature and various predictors. This same approach may be used to derive forecast guidance for locations without data for other weather elements.

A method of establishing a complete description of the summer (December to February) mean maximum temperature climatology in Victoria's East Central district was developed employing regression techniques, with the mean maximum temperature being set as a function of latitude, longitude, altitude and distance from the sea. The relationship so derived was:

Max = 47.0 - 3.61 x (latitude in degrees-30) + 1.25 x (longitude in degrees-145)
- 0.009 x (altitude in metres) + 0.217 x distance from sea in km, up to 5km)

with all predictors proving to be significant at the 95% level. The physical processes are reflected by the terms in the equation, namely a strong trend towards higher temperatures as one goes north (greater insolation and greater distance from the cooling influence of the sea), a weaker trend towards higher temperatures as one goes east (slightly greater distance from the cooling influence of the sea), a trend towards lower temperatures with increasing altitude (adiabatic effects), and a sharp trend towards lower temperatures in the immediate vicinity of the sea as one moves closer to the shore (the cooling effect of the sea being amplified near to the shore via agency of sea breezes).

Data forecast by the equation explained 82% of the variance and Fig 1 illustrates the strong relationship between "forecasts" of the mean maximum temperature and actual "observed" mean maximum temperatures.

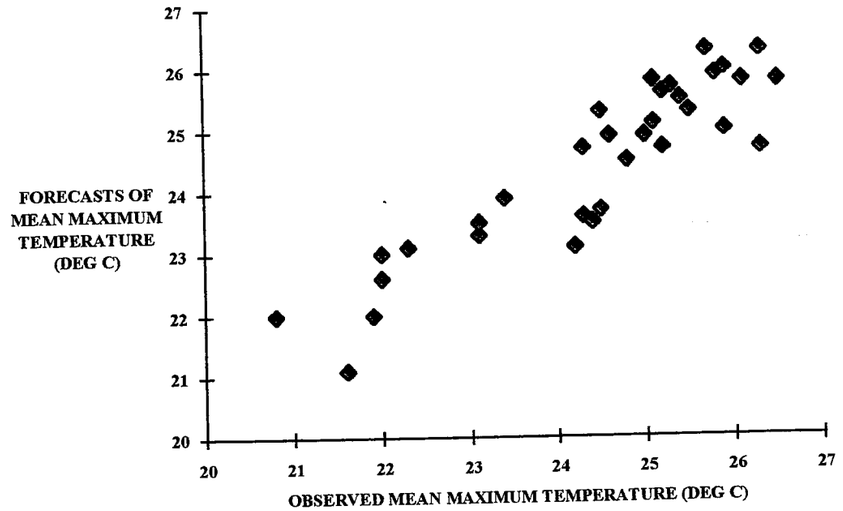

Fig 1 Depiction of the relationship between the observed mean maximum temperatures and those forecast by the equation.

4. A fully integrated system

To summarise, key characteristics that a more complex and fully integrated system might possess are now presented.

Firstly, the system would provide the forecaster with the capacity to obtain weather forecasting guidance for all weather elements at any location. Secondly, the system would provide that guidance in qualitative (worded) and quantitative terms. Thirdly, the system would provide a measure of the likely accuracy of the guidance.

Forecasting guidance for any location may be achieved by means of parameter enveloping (Stern, 1994 a&b) Generalised Analogue Statistics Model (GASM) spot forecasts for nearby localities (say, within 250 km) about their respective geographical and physical characteristics.

Examples of such characteristics could include, for example, latitude (p_1), longitude (p_2), altitude (p_3) and distance from the sea (p_4), square root of the distance from the sea (to take into account its exponentially diminishing impact as it increases), u and v components of slope, etc.

To illustrate by means of an example, for elements expressed as a numerical value (for example, maximum temperature (M)), spot forecasts of maximum temperature predictions for n nearby localities (M_1, M_2, ...M_n) may be parameter enveloped about latitude (p_1), longitude (p_2), altitude (p_3) and distance (or square root of distance) from the sea (p_4) in a regression equation of the form following, where in application, the constants in the regression equation - the C_i are derived by using the n sets of data M_j , p_{1j} , p_{2j} , p_{3j} , p_{4j} where i = 1,2 ... 15 and j = 1,2 ..... n.

$$M = C_0 + C_1p_1 + C_2p_2 + C_3p_3 + C_4p_4$$
$$C_5p_1p_2 + C_6p_1p_3 + C_7p_1p_4 + C_8p_2p_3 + C_9p_2p_4 + C_{10}p_3p_4 +$$
$$C_{11}p_1p_2p_3 + C_{12}p_1p_2p_4 + C_{13}p_1p_3p_4 + C_{14}p_2p_3p_4$$
$$+C_{15}p_1p_2p_3p_4$$

For elements expressed in terms of probability, for example, probability of thunderstorms, an analogous procedure is followed and because the worded component of the guidance is derived from probability based predictands, the source of the words is similarly derived.

5. Conclusion

The problem of extending the synoptic and weather data bases' short records and filling associated gaps has been discussed. In conclusion, the approach described may be used to derive guidance across the complete range of forecast locations and elements using the generalised version of the GASM (Dahni and Stern, 1995) as a platform. Indeed, an elevation correction methodology already forms the basis for interactive analysis of "real-time" temperature data (Dahni, 1997) on the Australian Integrated Forecast System (AIFS) (Barclay and Butt, 1988; Love, 1994; Dahni, 1995; Gigliotti, 1995; Dahni, 1996 a&b).

6. References

Annette P (1980) *Personal communication.*

Barclay PA and Butt IC (1988) Automation of regional forecasting centres in Australia. *Preprints, 4th Int. Conf. on Interactive Information and Processing Systems for Meteorology, Oceanography and Hydrology. Anaheim, Calif., 1-5 February 1988, Amer. Meteor. Soc., 21-24.*

Dahni RR (1988) The development of an operational analogue statistics model to produce weather forecast guidance. *Ph. D. Thesis, Department of Meteorology, University of Melbourne, Australia.*

Dahni RR (1995) Techniques development program (September to December 1995). *Attachment to Gigliotti (1995b).*

Dahni RR (1996a) Generalised Analogue Statistics Model Version 1.8 Reference Manual. *Internal Bur. Met., Australia Doc.*

Dahni RR (1996b) Forecast Guidance System User Guide. *Internal Bur. Met., Australia Doc.*

Dahni RR (1997) Map Analysis 1.2 User Guide. *Internal Bur. Met., Australia Doc.*

Dahni RR and Stern H (1995) The development of a generalised UNIX version of the Victorian Regional Office's operational analogue statistics model. *BMRC Res. Rep. 47, Bur. Met., Australia,* 34 pp.

Gibson JK Hernandez A Kallberg P Nomura A Serrano E and Uppala U (1994) The ECMWF re-analysis (ERA) project - plans and current status. *Preprints, 10th Conference on Numerical Weather Prediction, July 18-22, 1994, Portland, Oregon, Amer. Meteor. Soc.*, 288-291.

Gigliotti P (1995) AIFS progress report 7 September 1995. *Internal Bur. Met., Australia Doc.*

Janowiak JE Ebisuzaki W Chelliah M Surunjana S Kistler R Kanamitsu M and White G (1994) Reanalysis archives. *Preprints, 10th Conf. on Numerical Weather Prediction, July 18-22, 1994, Portland, Oregon, Amer. Meteor. Soc.*, 286-287.

Jenne R (1994) The reanalysis database. *Preprints, 10th Conf. on Numerical Weather Prediction, July 18-22, 1994, Portland, Oregon, Amer. Meteor. Soc.*, 284-285.

Kingtse CM and Wang XL (1994) Impact of satellite data on the CDAS/Reanalysis system. *Preprints, 10th Conf. on Numerical Weather Prediction, July 18-22, 1994, Portland, Oregon, Amer. Meteor. Soc.*, 281-283.

Kistler R Kanamitsu M and Kalnay E (1994) Overview of the NMC/NCAR reanalysis system. *Preprints, 10th Conf. on Numerical Weather Prediction, July 18-22, 1994, Portland, Oregon, Amer. Meteor. Soc.*, 279-280.

Love G (1994) An Australian integrated forecast system. *Int. Conf. on Interactive Information and Processing Systems for Meteorology, Oceanography and Hydrology, Amer. Meteor. Soc., Jan 23-28, 1994, Nashville, Tennessee.*

Stern H (1980) The development of an automated system of forecasting guidance using analogue retrieval techniques. *M. Sc. Thesis, Department of Meteorology, University of Melbourne* (see also Stern (1985), which refers to a subsequent publication as *Meteor. Study 35, Bur. Met., Australia*).

Stern H (1994a) Enveloping predictor parameters in a regression equation - an alternative to model output statistics (MOS). *Abstracts, 10th Conf. Numerical Weather Prediction, Amer. Meteor. Soc.*

Stern H (1996) Statistically based weather forecast guidance. *Ph. D. Thesis, School of Earth Sciences, University of Melbourne, Australia.*

Stern H de la Lande J Dahni RR Jasper JD and Wilson K (1985) Meso-scale forecasting guidance at the Victorian Regional Office. *Bur. Met., Australia Training Note 2, Operational Forecasting, Papers for the Senior Forecasters Conf., June 1985.*