2B.2 DEFINING COGNITIVE DECISION MAKING PROCESSES IN FORECASTING: A KNOWLEDGE BASED SYSTEM TO GENERATE WEATHER GRAPHICS.

Harvey Stern *

Bureau of Meteorology, Australia

1. INTRODUCTION

'Combining forecasts by mathematically aggregating a number of individual forecasts increases the reliability of forecasts (Kelley, 1925; Stroop, 1932) and averages out unsystematic errors (but not systematic biases) in cue utilization. A common method for combining individual forecasts is to calculate an equal weighted average of individual forecasts' (Armstrong, 2001).

The work to be presented here represents a vindication of Armstrong and others, who have long advocated combining forecasts.

It suggests adopting a strategy, in the context of predicting Melbourne's weather, that has the potential to bring about forecasts that are substantially more accurate than those currently issued officially.

2. BACKGROUND

Decision-making processes leading to a weather forecast are multi-faceted. Some of the issues considered by forecasters in arriving at their decision include:

-Climatology;

-The relevance of recent weather patterns to the evolution of the current weather pattern;

-The weather suggested by:

-Guidance from the direct numerical prediction model (NWP) output;

-Guidance that is based upon a statistical interpretation of the NWP model output; and,

-Subjective interpretation of the NWP model output, based upon forecaster experience;

-Confidence in the synoptic evolution suggested by the NWP output;

-Strategies for addressing issues such as conflicting guidance; and,

-Criteria for amending the current forecast previously issued by their colleagues.

3. PURPOSE

It is the purpose of this work to attempt to objectively describe these decision-making processes via a computerised weather forecasting system that operates in a manner to replicate the aforementioned processes.

In this context, a test of how successfully the said processes are being replicated by the computerised weather forecasting system lies in the extent to which the output (and overall performance) of the computerised weather forecasting system mimics the output (and overall performance) of the officially issued product.

4. A KNOWLEDGE BASED FORECASTING SYSTEM

Over recent years, the present author has been involved in the development of a knowledge based weather forecasting system (Stern, 2002, 2003, 2004a, 2005).

Various components of the system may be used to automatically generate worded weather forecasts for the general public, terminal aerodrome forecasts (TAFs) for aviation interests, and marine forecasts for the boating fraternity.

The knowledge based system generates these products by using a range of forecasting aids to interpret NWP model output in terms of such weather parameters as precipitation amount and probability, maximum and minimum temperature, fog and low cloud probability (Stern and Parkyn, 2001), thunderstorm probability (Stern, 2004b), wind direction and speed, and swell (Dawkins, 2002).

Recently, the knowledge based system was used to explore the limits of predictability (Stern, 2004a).

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* *Corresponding author address:* Harvey Stern, Bureau of Meteorology, Box 1636, Melbourne, Vic., 3001, Australia; e-mail: h.stern@bom.gov.au

The outcome of this investigation was to reveal a modest level of skill at predicting the temperature up to 10 days in advance, but skill at predicting precipitation was limited to 7 days in advance

5. THE CURRENT APPLICATION

The system is utilised to define and evaluate the cognitive decision making processes involved in the generation of extended-range day-to-day weather forecasts.

Specifically, the weather forecasting product examined in the present work is that of weather graphics. Fourteen different weather graphics (selected from Australian Bureau of Meteorology and World Meteorology Organisation graphics) are utilised (Figure 1).

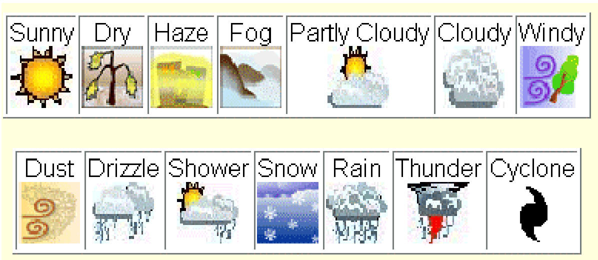

Figure 1. The individual weather graphics that are utilised.

6. STRATEGY

The National Oceanic and Atmospheric Administration's (NOAA) Global Forecasting System (GFSx) NWP model

http://www.arl.noaa.gov/ready/metdata.html

provides output that includes forecast data every 6 hours from forecast hours 0 to 180 on a 1 degree latitude/longitude grid covering the globe. In addition, this data is mapped to northern and southern hemispheric 257 x 257 grids. The data is updated 4 times per day. The knowledge based forecasting system was utilised to objectively interpret the output of the GFSx model statistically in terms of local weather at Melbourne.

Forecasts of maximum temperature, minimum temperature, probability of precipitation, amount of precipitation, in addition to a weather graphic depicting the expected weather during the morning, and a weather graphic depicting the expected weather during the afternoon, are all generated, in order to rigorously establish how successfully the system incorporates NWP uncertainty into forecasts.

The criteria that forecasters utilise in amending the current forecast previously issued by their colleagues, is replicated in the knowledge based system, by preventing the system from changing temperature forecasts, from one preparation to the next, by less than 2 deg C.

These forecasts are generated for Melbourne, and also for 18 nearby locations (Figure 2).

Figure 2. A map of the Melbourne area.

7. THE ALGORITHM

The weather graphics (Figure 3) are generated from an algorithm that has a logical process to yield HTML code by combining predictions of:

- temperature – Figure 4;
- precipitation;
- phenomena (for example, fog – Figure 5, thunder, and dust); and,
- morning and afternoon weather (Figure 6),

with features of the forecast synoptic type (strength, direction, and cyclonicity of the surface flow).

Day & Date	Morning	Afternoon	Min Temp (deg C)	Max Temp (deg C)	Precip Amount (mm)	Precip Prob (%)
Mon-16-5-2005	Fog.	Partly Cloudy.	8	18	0	44
Tue-17-5-2005	Fog.	Haze.	8	19	0	11
Wed-18-5-2005	Partly Cloudy.	Partly Cloudy.	8	18	0	31
Thu-19-5-2005	Sunny.	Partly Cloudy.	6	17	0	6
Fri-20-5-2005	Partly Cloudy.	Cloudy.	6	18	0	24
Sat-21-5-2005	Cloudy.	Shower.	9	18	0.4	58
Sun-22-5-2005	Shower.	Rain.	10	20	3.2	73

Figure 3. An example of the generated weather graphic product.

```
        case 37:
minf=
-0.956
+0.678*sin-1.774*cosin
+0.357*max-0.0506*max*sin+0.0844*max*cosin
+0.0970*pr-0.0426*pr*sin+0.0523*pr*cosin
+0.177*temp-0.0339*temp*sin-0.0772*temp*cosin
+0.252*min+0.0748*min*sin-0.0641*min*cosin;
        break;
```

Figure 4. Extract of code to generate minimum temperature.

```
     break;
     case 22:
     pfog=100*
  (Math.exp(-4.639+0.293*dpt-0.117*max+0.023*mon))/
(1+Math.exp(-4.639+0.293*dpt-0.117*max+0.023*mon));
     break;
     case 23:
```

Figure 5. Extract of code to generate fog probability.

```
  else if (type=="45" && popfinal<70)
  {iconmorningzero="Drizzle.";
   iconafternoonzero="Drizzle.";}
  else if (type=="45" && popfinal<80)
  {iconmorningzero="Rain.";
   iconafternoonzero="Rain.";}
  else if (type=="45")
  {iconmorningzero="Rain.";
   iconafternoonzero="Rain.";}
//TYPE 46 STRONG ANTICYCLONIC ESE
  else if (type=="46" && popfinal<5)
  {iconmorningzero="Sunny.";
   iconafternoonzero="Sunny.";}
  else if (type=="46" && popfinal<20)
  {iconmorningzero="Partly Cloudy.";
   iconafternoonzero="Sunny.";}
```

Figure 6. Extract of code to generate morning and afternoon weather graphic icons.

8. A 100-DAY TRIAL

A 100-day trial (Feb 14, 2005 to May 24, 2005) of its performance was conducted, with the knowledge based system generating twice-daily forecasts out to seven days in advance.

During the trial, the overall percentage variance of observed weather explained by the forecasts so generated (the system's forecasts) was 43.24% compared with 42.31% for the official forecasts (Figure 7).

That the knowledge based system has achieved some success in its attempt to replicate the cognitive decision making processes in forecasting is confirmed by the closeness of the overall percentage variances explained by the two sets of forecasts.

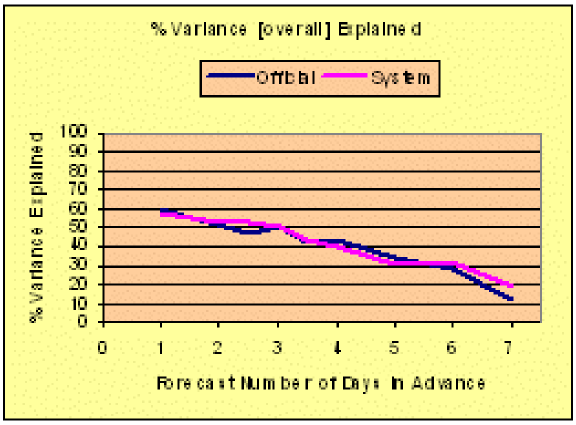

Figure 7. The overall percentage variance of observed weather explained by the forecasts.

<u>Specifically for temperature</u>, the percentage variance explained by the 1000 minimum temperature forecasts (Day 1 to Day 7 00 UTC forecasts, and Day 2 to Day 4 12 UTC forecasts) and 1100 maximum temperature forecasts (Day 1 to Day 7 00 UTC forecasts, and Day 1 to Day 4 12 UTC forecasts) so generated was 59.71% compared with 59.55% explained by the official forecasts. The Root Mean Square (RMS) Error of the forecasts so generated was 2.55 deg C compared with 2.45 deg C for the official forecasts (Figure 8).

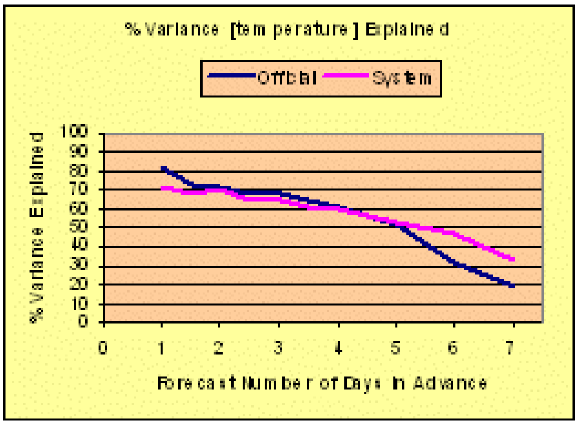

Figure 8. The overall percentage variance of observed temperature explained by the forecasts.

<u>Specifically for precipitation</u>, the percentage variance explained by the 1100 quantitative precipitation forecasts (Day 1 to Day 7 00 UTC forecasts, and Day 1 to Day 4 12 UTC forecasts) and 1100 probability of precipitation forecasts (Day 1 to Day 7 00 UTC forecasts, and Day 1 to Day 4 12 UTC forecasts) so generated was 26.78% compared with 25.07% explained by the official forecasts. On a rain/no rain basis, the percentage correct forecasts so generated were 78.82% compared with 77.64% of the official forecasts (Figure 9).

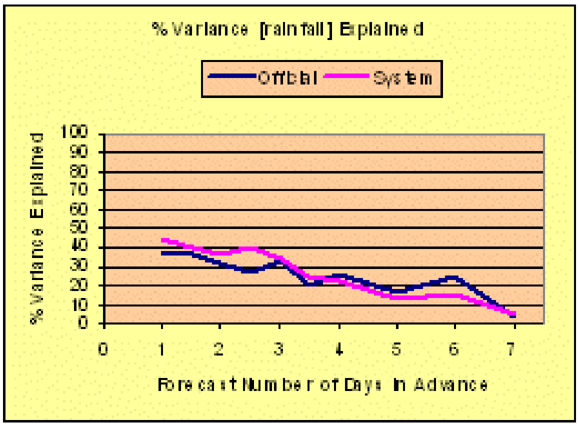

Figure 9. The overall percentage variance of observed rainfall explained by the forecasts.

However, <u>the overall percentage variance of official forecasts</u> explained by the system's forecasts was only 45.91%. This was made up of 63.59% of the variance of officially forecast temperature, and 28.23% of the variance of officially forecast precipitation.

This indicates, that, on a day-to-day basis, there are significant aspects of the processes employed in deriving the official forecasts that are not taken into account by the system's forecasts, and vice versa.

9. CONSENSUS FORECASTS

Regarding the two sets of forecasts as partially independent and utilising linear regression to optimally combine the estimates of minimum temperature, maximum temperature, precipitation amount, and precipitation probability, lifts the overall percentage variance of observed weather explained.

It suggests that adopting such a strategy of optimally combining the official and system predictions has the potential to deliver a set of forecasts that are substantially more accurate than those currently issued officially.

The overall percentage variance of observed weather explained is lifted (by the consensus forecasts) to 50.21% from 43.24% (system) and 42.31% (official);

Specifically for temperature, the percentage variance explained is lifted (by the consensus forecasts) to 66.33% from 59.71% (system) and 59.55% (official), whilst the RMS Error is reduced to 2.25 deg C from 2.55 deg C (system) and 2.45 deg C (official);

Specifically for precipitation, the percentage variance explained is lifted (by the consensus forecasts) to 34.09% from 26.78% (system) and 25.07% (official), whilst on a rain/no rain basis, the percentage correct forecasts are lifted to 83.55% from 78.82% (system) and 77.64% (official).

10 FUTURE WORK

In the context of the extensive body of literature in support of systematically combining forecasts, it is planned to incorporate the aforementioned optimal consensus process into the knowledge based system. For an update on progress with this work, readers may visit the website

http://www.weather-climate.com/forecasting.html

11. REFERENCES

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Acknowledgments. To Stuart Coombs (from the Victorian Regional Forecasting Centre), for drawing attention to the skill displayed by the NOAA Global Forecasting System, to Marco Berghege (from The Netherlands) for his suggestion regarding the programming utilised herein, to Neville Nicholls and Frank Woodcock (of the Bureau of Meteorology Research Centre – BMRC), for their comments on combining forecasts, to Noel Davidson (also of BMRC), for his comments on the NWP output, and to my other Bureau of Meteorology colleagues for their helpful discussions and feedback.