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Project Title: Development of a Heat-Health Warning System for Glasgow, Montana: A Prototype for Small Population Areas

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PROJECT OBJECTIVES AND ACCOMPLISHMENTS

The general scope of the project was to improve the operational issuance of guidance and warning/advisory products for human heat stress based on a more advanced understanding of how human physiology relates to air masses and weather than is obtained from simply using the heat index. Thus, a "heat health watch warning system" (HHWS) was developed for the Glasgow, MT WFO which is now being utilized as primary guidance in the issuance of excessive heat warnings and advisories.

This problem is relevant to almost all areas of the country, including the Glasgow warning area, because heat waves periodically occur almost everywhere (Ebi et al., 2003; Kalkstein et al., 2008). Even in cool climates, a heat wave, which might be unremarkable in a hot climate, can create significant stress because the population is not acclimated to heat. In the Glasgow, Montana area, in particular, there are occasionally strong heat waves which stress the rural population not accostomed to such weather. July of 2007, for example, saw a record heat wave in the Glasgow area with high and low temperatures over 20°F above normal.

The approach used in this study is to take the heat/health watch warning system currently being widely applied by one of the PIs to urban areas across the country, and apply it, for the first time, to a rural area with a small population. This system uses an analysis of air mass types and correlates this with historical mortality data, seasonal factors, and social factors. The system is designed to predict mortality risk based on the synoptic conditions, the duration of the event, and the time of year. This problem is complicated by the lack of a large population in rural areas on which to base statistics of excessive deaths versus air mass types, as is done for urban areas.

In our six month report, we discussed that there were four potential ways that we might achieve these ends. Ultimately, we decided to aggregate the large rural area together to see if we could determine an air mass/mortality signal for this entire area (Figure 1). We determined that several hundred thousand people resided in this total area, which could potentially be a sufficient population to permit the development of a statistically significant heat/health relationship, using an air mass-based approach similar to many of our other existing systems. We had hoped to gain daily mortality data from a relatively nearby large city, Regina, Saskatchewan, but unfortunately we were unable to obtain those data in a timely manner.

Statistical Relationships

Thirty years of daily all-cause mortality data (1975-2004) were available on a county-by-county basis for all the counties aggregated in Figure 1. These were standardized to account for changes in population within the region, and to eliminate as many daily variations not attributed to meteorology as possible. The standardized data were then related to the spatial synoptic air mass (SSC) categorizations as described in Sheridan and Kalkstein (2004), and it was determined that two air mass types were, in fact, significantly related to variations in mortality over the multi-county region.

Table 1 shows the frequency of the various air masses in Glasgow over the 4500+ days evaluated. Historically, dry tropical (DT) air masses and moist tropical (MT) air masses contribute to elevated mortality and are frequently responsible for the most oppressive weather during excessive heat episodes. In Glasgow, one subdivision of DT air, DT+, and two subdivisions of MT air, the MT+ and MT++ subsets, were particularly related to higher mortality. All of these subsets are associated with higher than average temperatures and dewpoints during DT and MT air intrusions. Fortunately, these air masses occur relatively infrequently; DT+ air masses occur on slightly more than 1% of days in an average summer in Glasgow, and MT+ and MT++ air masses are exceedingly rare, together occurring on 0.4% of days in an average summer.

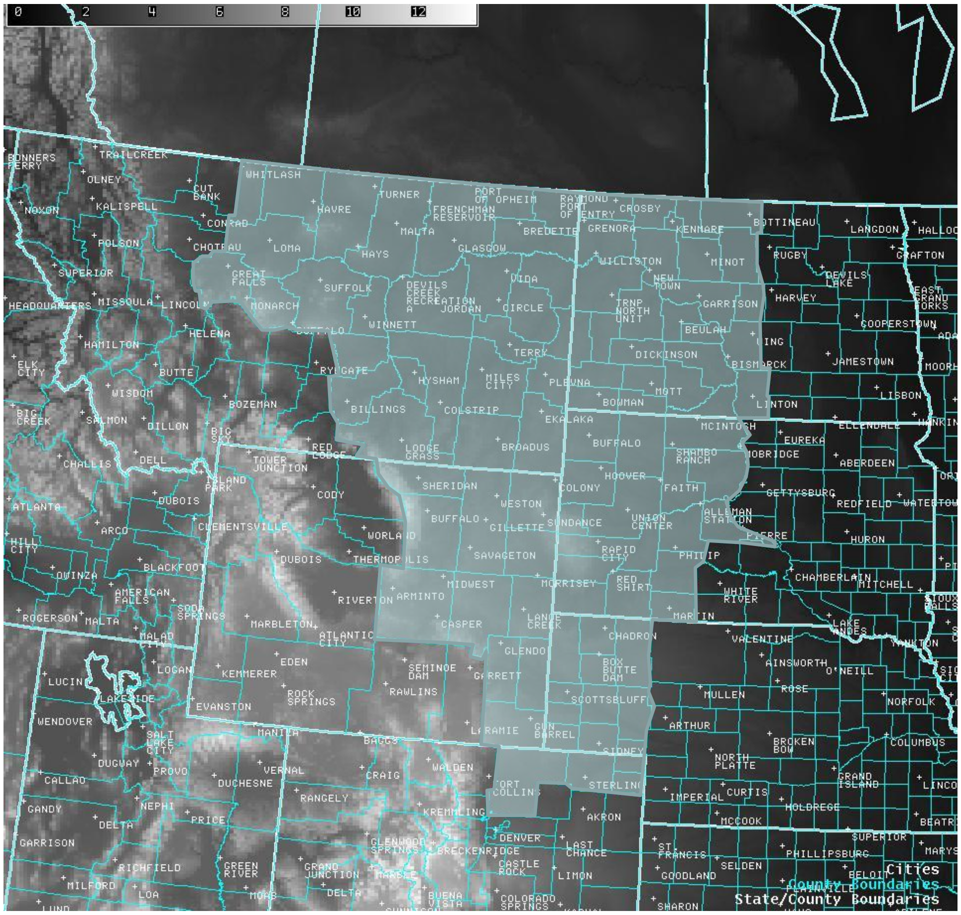

Figure 1. Counties used for population aggregation for the Glasgow HHWS. The total population of the shaded region is approximately 700,000 people.

It is apparent that excess mortality is associated with these particular oppressive air masses (Table 2). For DT+ and MT+, there is a positive anomaly in mortality for the months of June and July. For example, in June, DT+ shows a mean daily mortality excess of 0.71, indicating that the average daily increase is just less than ¾ deaths. This is not an insignificant number, considering that an average of only 7 people die daily in the multi-county region surrounding Glasgow; thus, 0.71 represents about a 10 percent increase in mortality on average during DT+ days. The number for MT+ in July is even higher; there is a mean daily increase of 1.03 deaths in the multi-county area, which represents an almost 15% increase in mortality. Clearly, the largest anomalies are during those rare

MT++ days, particularly June and August (July appears to be a statistical artifact). The mean daily increases exceed 20% in those months, and the 1.96 mean daily excess deaths in June approaches a 30% increase. There are also some increases in other months, particularly during DT air mass intrusions in May. At present, we have designed the system to pinpoint only the three most oppressive air masses: DT+, MT+, and MT++.

FREQUENCY OF SSC TYPES											
	DM	**DP**	**DT**	**MM**	**MP**	**MT**	**TR**	**DT+**	**MT+**	**MT++**	**TOTAL**
MAY	346	229	63	58	119	24	80	8	1	0	928
JUN	262	265	42	72	110	59	74	11	1	1	897
JUL	372	180	103	59	51	85	61	7	6	3	927
AUG	351	138	168	74	52	55	63	15	2	1	919
SEP	335	206	91	47	117	15	79	6	0	1	897
TOTAL	1666	1018	467	310	449	238	357	47	10	6	4568

Table 1. Frequency of air mass types at Glasgow, MT for the period 1948-present. Thankfully, the three offensive air masses, highlighted in red, occur rarely.

MEAN ANOMALOUS MORTALITY FOR GGW BY SSC TYPE											
	DM	**DP**	**DT**	**MM**	**MP**	**MT**	**TR**	**DT+**	**MT+**	**MT++**	**TOTAL**
MAY	0.07	0.05	0.48	0.08	-0.30	-0.47	0.42	-0.33	-2.27		0.06
JUN	0.00	-0.10	-0.36	-0.24	-0.38	0.17	-0.20	0.71	0.66	1.96	-0.10
JUL	-0.20	-0.05	0.10	0.15	0.24	-0.09	-0.58	0.31	1.03	-0.02	-0.09
AUG	-0.28	-0.37	-0.02	-0.50	-0.35	0.16	-0.32	-0.62	-0.37	1.63	-0.25
SEP	0.00	0.05	0.16	-0.25	-0.14	-0.35	-0.08	-2.21		-2.37	-0.03
TOTAL	-0.09	-0.06	0.08	-0.17	-0.22	-0.02	-0.12	-0.33	0.38	0.19	-0.08

Table 2. Daily mean variation of mortality from the summer baseline. There are an average of 7 deaths daily in the highlighted region, so a value of 0.70 would represent a 10% increase in mean daily mortality.

System Development

The results were surprisingly strong, particularly considering the spatial extent of the area evaluated. Clearly we were able to utilize these results in the construction of a HHWS for the Glasgow WFO. Based on the magnitude of mortality increase across oppressive air masses and months, we devised a system to call heat advisories and excessive heat warnings (Table3). The greatest mean daily mortality increases were uncovered for DT+ and MT+ air masses in June and July, as illustrated in Figure 3. Thus, excessive heat warnings are recommended by the system in those months when these two air masses are present. For MT++, the greatest increases were found during June and August; we deemed the insignificant July results to be a statistical anomaly, since there is no reason why June and August should be so high while July would not be. Thus, the system recommends excessive heat warnings to be called during June, July, and August on all MT++ days. For August and September, the system recommends that heat advisories should be called when these air masses are present (except for MT++, when a warning is suggested).

ADVISORY AND WARNING			
	DT+	MT+	MT++
MAY			
JUN	0.37	0.03	0.03
JUL	0.23	0.20	0.10
AUG	0.50	0.07	0.03
SEP	0.20	0.00	0.03

Table 3. Recommended advisory and warning calls for Glasgow. Bright red indicates warning, orange indicates advisory. The numbers within the boxes represent the average percentage of times these air masses are present each month.

The password-protected website for the Glasgow HHWS is illustrated in Figure 2. This website is updated at least twice a day, based upon the issuance of PFMs at the Glasgow WFO. However, the system checks for forecast updates every 15 minutes and recalculates air mass type accordingly.

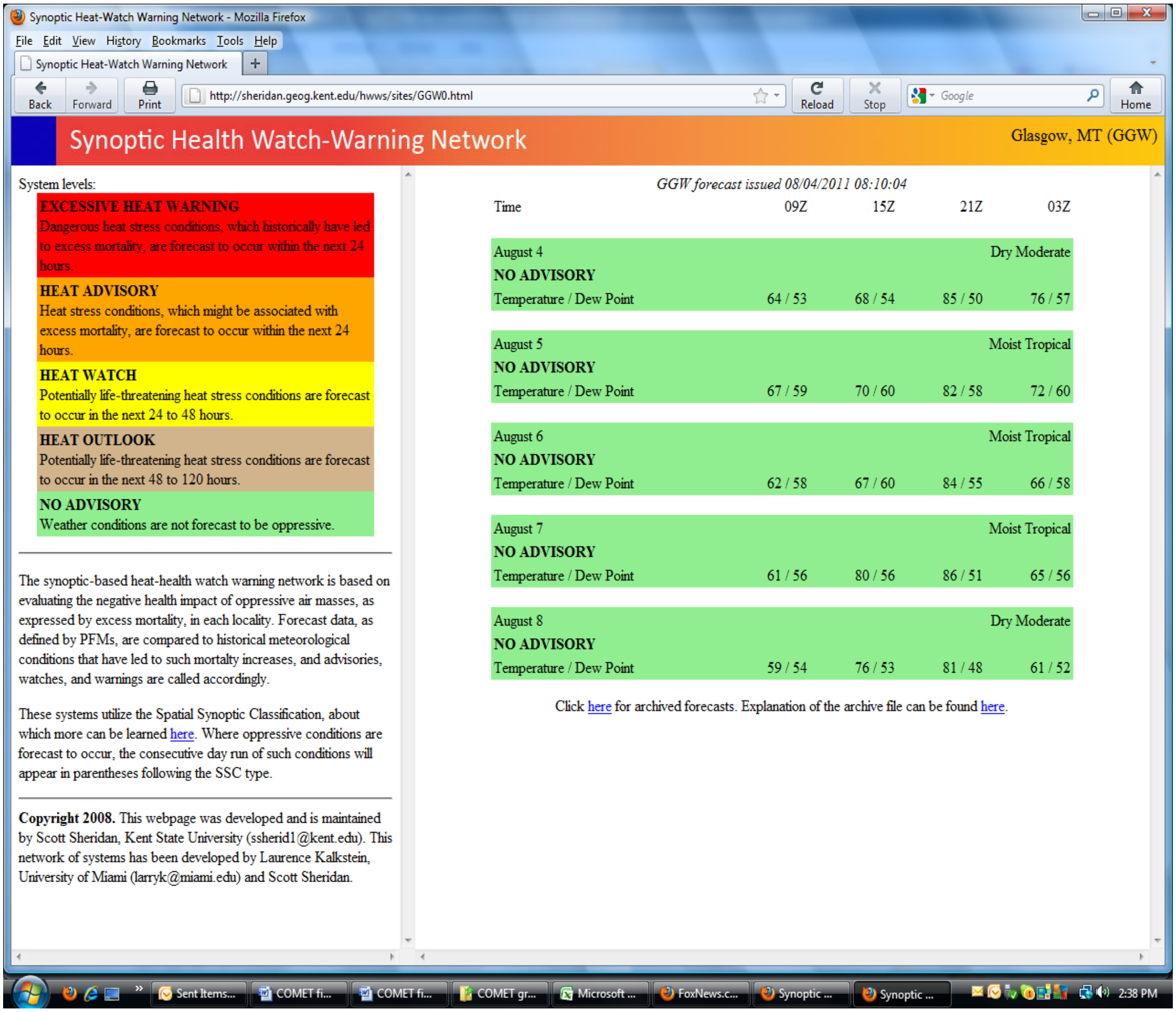

Figure 2. Example webpage for the Glasgow HHWS.

Forecasts extend out 5 days. The website not only shows color-coded bars to alert forecasters when watches, advisories, or warnings are suggested, it also indicates the forecast temperature and dewpoint four times a day and the air mass type forecast for the Glasgow region.

The frequency of advisory and/or warning calls is rather low because of the extreme climate of Glasgow as indicated by the percentage frequencies within Table 3. For example, DT+ occurs in June on 0.37% of days and it is even rarer in July (0.23%). The frequency of occurrence of the other air masses is even rarer. Based on these frequencies, during an average summer (May 15-September), there will be one warning day per season and 0.8 advisory day per season. Of course, this will vary from year to year (Table 4); in a number of years, no warnings or advisories would be called, while in others (e.g. 1983, 1988, 2003) five or more would be called in a summer. However, in general, the number of calls for Glasgow is less frequent than for most regions in the United States.

Row Labels	SUM	Warn	Adv
1975	3	3	0
1976	1	0	1
1977	0	0	0
1978	1	0	1
1979	0	0	0
1980	0	0	0
1981	0	0	0
1982	0	0	0
1983	**8**	3	**5**
1984	2	2	0
1985	0	0	0
1986	2	2	0
1987	4	4	0
1988	**7**	7	0
1989	2	1	1
1990	1	1	0
1991	2	0	2
1992	0	0	0
1993	0	0	0
1994	0	0	0
1995	1	1	0
1996	2	2	0
1997	1	0	1
1998	4	0	4
1999	0	0	0
2000	3	1	2
2001	4	2	2
2002	1	1	0
2003	5	0	5
2004	0	0	0
Grand Total	54	30	24

Table 4. Number of calls system would have made if operating from 1975-2004. Red indicates number of calls exceeds 4; yellow indicates number of calls exceeds 3.

SUMMARY OF BENEFITS

A fully-operational heat health warning system is now running for the Glasgow WFO and is located on a password-protected website that is updated at least twice daily, and more frequently if the Office issues forecast changes. The forecasters have been fully briefed on the operation of the system, and it is now being used as guidance to call advisories and warnings by the forecasters. The WCM has contacted stakeholders and made them aware of the system. A briefing is planned for all stakeholders in the near future to make certain that they know how the system operates, how it is better than the old heat warning criteria, and how they can use the information to enhance their own county or local intervention activities.

The system has also been mainstreamed into the suite of HHWSs already operating by NWS Forecast Offices (http://sheridan.geog.kent.edu/hwws/). Thus, the Glasgow system is part of the nationalization of synoptic-based heat/health warning systems for every WFO in the country.

Finally, this represents the second small-population system that we have established. Virtually all other systems are for large metropolitan areas, with populations often greater than 1,000,000 people. Only LaCrosse, WI and Glasgow have systems for small-population areas, and these present a special challenge. Glasgow's system was even more difficult than LaCrosse's; the latter is between two major metropolitan areas: Minneapolis and Chicago. We had already established systems for those locales, and we were able to modify LaCrosse's system as a kind of hybrid between the two big metro systems. For Glasgow, there are no major population centers for hundreds of miles; thus, we had to devise a procedure that was unique for small population areas that are remote. This will assist in the development of other remote small population systems, like Bismarck, ND and Rapid City, SD.

APPLICATION OF SYSTEM BY WFO GLASGOW

Once the HHWS website was prepared, WFO Glasgow (GGW) trained its staff on the use and interpretation of the system. GGW also modified its criteria for issuing heat products so as to take advantage of the new tool. It was decided that a recommendation by the HHWS for a product would not be the sole criteria on which to base the decision to issue a product. The previous criteria GGW had used were left in place with additional criteria related to the HHWS added. The previous criteria were very strong and resulted in heat products virtually never being issued. The addition of the HHWS allowed situations to be considered for heat products that would not have been previously selected. The guidelines for the staff on use of the HHWS, incorporate it as a tool to be considered along with the heat index and duration of the event. Staff were advised to issue a warning or advisory if the HHWS recommended such a product, and the event was to last for 2 or more days, and the heat index was forecast to exceed 99° F.

Filtering the HHWS by the heat index allows forecasters to delineate areas in the forecast domain that should have a heat product. Also, this solves one of the potential problems with the aggregation method. Using a multistate area to aggregate the statistics could lead to a bias as some parts of the domain may be typically hotter than others when under the same air mass, with the excess deaths possibly occurring more often in some areas of the aggregation domain than others. Typically, hot air masses result from large high pressure systems which generate homogenous conditions over a wide area, so it is not clear if this is really a problem; however, relating the HHWS to the heat index map allows staff to see what areas are really under stress. GGW issued a Heat Advisory for July 18-19 based on application of this system. On these dates, temperature and humidity values were very consistent over the entire aggregation area of Fig. 1.

PRESENTATIONS AND PUBLICATIONS

There will be at least one public workshop on the operation of the system for stakeholders in the area. We will present a paper on system development and operation at the New Orleans AMS annual meeting. We will also travel to adjacent WFOs with small populations to discuss with them how our system is developed and managed as we continue to expand HHWSs around the country. We hope to publish a manuscript on the system in a peer-reviewed journal. Work was presented at a regional Conference (Schnetzler et al., 2010).

RELATED ACCOMPLISHMENTS

The development of this HHWS, and also of our CANL system, has made it to the newspapers in the Miami area, where it is considered unique that University of Miami faculty and graduate students are working with a Weather Forecast Office in the Northern Plains!

SUMMARY OF PROBLEMS ENCOUNTERED

The biggest problem related to the development of the most efficient means to construct the system. We attempted to gain mortality data from a relatively nearby Canadian city, Regina, with little success. However, the development of a large study area which included many rural counties worked out fine, the results came out to be more robust, and we have full confidence in the system.

Other than this, no problems were encountered.

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