Severe Local Storm Forecasting
-the development of a warning system

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Abstract
For decades now the forecasting of severe local storms in Belize has been a subjective process based on the whims and discretion of the individual forecaster. This is a primary attempt at producing forecasting techniques for such events based on empirical derivations of key indicators to such an outburst. As more local knowledge is gained about the evolution of such weather phenomena more refinements will be made to these techniques. The ultimate aim of this research is the production of a severe local storm forecasting worksheet based on derived key indicators. This work subsequently led to the implementation of a severe weather watch and warning system for the country of Belize.

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1) Introduction

It has been observed that during the dry season in Belize i.e. March through May there are sporadic outbreaks of thunderstorms activity particularly during the late evening towards night-time. A heated boundary layer conditions in collaboration with mesoscale lifting mechanisms provide a suitable environment for such episodes which in instances can be of the severe variety. Before proceeding, however, it is imperative that a definition of a severe local storm be brought to the forefront. The Severe Local Storms Unit (SELS) of the National Severe Storms Forecast Center (NSSFC) of the U.S. Weather Service defines a severe weather phenomenon as encompassing systems which include a) tornadoes

b) damaging winds or measured gusts ≥ 50kts.

c) hail of diameter ≥ ¾ in.

A redefinition of these criteria is deemed necessary in order to encompass the rarity of tornadoes and hail in Belize. Also due to the differences in the structural integrity of the vast majority ofbuildings the measured gust criterion would need to be lowered.(personal communication) Rather than include a particular hail diameter any occurrence of hail would warrant classification as a severe weather outbreak. A redefinition of a severe weather outbreak for Belize would be :

a) any occurrence of a tornado
b) damaging winds or measured gusts in excess of 35 Kt.
c) any occurrence of hail.

Three distinct elements must be considered in the forecasting of severe local storms.(1) Doswell et al 1992. The first of these being climatology dictates the time of the year when these outbreaks are most likely to occur. In Belize this time is during the dry season-March through May with the highest probability of occurrence noted in May.

Secondly, pattern recognition entails the observation of certain synoptic weather patterns conducive to a severe weather outbreak.

Thirdly and possibly the most variable in terms of threshold values is parameter evaluations. Characteristic to each severe local storm outbreak are certain numerical values ascribed to key indicators. These in conjunction with the other two aforementioned influences dictate the likelihood of a severe local storm outbreak. Since the climatological aspect is relatively straight-forward only the other two aspects will be considered in detail.

The first section of this paper deals with the method involved in the investigation of these severe storms in order to derive key signatures to such an outbreak. This section is further subdivided to include recognition of certain patterns and the evaluation of key parameters which can be used to forecast such an event. This is followed by a section dealing with the explanation to the relevancy to an outbreak of each of these key parameters.

2) Method

Eleven cases of severe weather outbreaks during the dry season formed the database for this investigation. The broad scale features typical of each individual event were first scrutinised. This formed the basis of the first set of indicators to a severe storm occurrence- the pattern recognition. Each case had associated with it some synoptic pattern which foretold of the <u>potential</u> for an outbreak of the severe variety. These patterns formed the upper atmospheric support in the form of divergence and/or vertical motion. A deep layered wind maxima, a trough at 300 and 200mb levels and/or mid level vorticity advection all formed a part of this pattern recognition process.

The other step was to identify mesoscale features and thermodynamic variables which could serve as lifting or triggering mechanisms. These would form the impetus for the low level convergence field which would be complimented by the upper level support features mentioned in the previous paragraph.

Threshold values for these variables were then found. A worksheet (See Figure 1) comprising of a checklist to be filled in as critical values of the variables are achieved was created. In conjunction with the development of this worksheet came a severe local storm warning system whereby if a certain number of these key parameters became evident a watch or warning may be issued as appropriate.

3) Relevancy of Key Indicators

This section deals with the meteorological significance of the key parameters used as indicators to a severe local storm outbreak.

<u>Description of Key Parameters in the Forecasting of a Severe Outbreak</u>

* Parameters that are absolutely necessary.

The numbers refer to parameter numbers in the worksheet.

*4d, d1) Lifting mechanism: Severe thunderstorms with hail or destructive winds do not develop spontaneously but require a lifting mechanism. These may be in the form of

i) cold front
ii) pre-frontal squall line
iii) warm front
iv) outflow boundary at the edge of a line of thunderstorms

SEVERE LOCAL STORM FORECASTING WORKSHEET

(Version 1.1)

Date:________________

Time:________________

Advisory Valid Until:______________________________

Forecaster:______________________________

The following is a checklist of key indicators to a severe weather outbreak. It is only valid between the months of March through May

PATTERN RECOGNITION		YES	NO
(1) **Wind Max**			
a) Upper level wind maximum pattern is strong and deep to be reflected at the mid levels (400 & 500 mb)	a)		
(2) **Upper Level Trough**			
b) Axis located within 1 to 7° west of station	b)		
(3) **500mb Vorticity Advection**			
c) Do the contours and vorticity isopleths suggest some Positive Vorticity Advection (PVA) over the area?	c)		

If answered **Yes** to any one of the above then proceed.

Figure 1

EVALUATED PARAMETERS		YES	NO
(4) **Lifting Mechanism**			
d) Is there a physical lifting mechanism?	d)		
(d1)If so, give type.____________________			
(5) **Temperatures**			
e) Forecast surface temperatures ≥ 33°C (Mar & Apr) ≥ 34.5 (May)	e)		
f) Forecast dew points ≥24.5°C	f)		
(6) **Stability Indices**			
g) K.I. >29.7	g)		
h) L.I. <0.0	h)		
(7) **Shear**			
i) Directional shear ($\partial\beta/\partial z$)	i)		
Sfc-18000ft magnitude of veering ≥45°			
(8) **24 hr 500mb Height Change**			
j) If answer to 4 (d1) is a cold front then is this change	j)		
+10dm or greater?			
If answer to 4 (d1) is not a cold front then is this change -10dm or greater			

Figure 1 (cont'd)

(9) **Moisture Variables**		YES	NO
Surface to 850mb			
k) Mean R.H. ≥60%?	k)		
l) (SfcDew + 850Dew)/2 ≥16.0?	l)		
(10) **1000- 500 mb Thickness**			
m) 5755m<ΔZ<5800m	m)		

If answered YES for 6 or more of the above then at this juncture issue a **SEVERE LOCAL STORM WATCH!!!**

(11) **Is there visual evidence of an outbreak on**		YES	NO
n) Satellite imagery?	n)		
o) Radar?	o)		
(12) **Have reports been received of such an outbreak?**	p)		

Figure 1 (cont'd)

If answered YES to any one of the three immediately above then issue a **SEVERE LOCAL STORM WARNING!!!!**

If not then proceed to items (13) and (14)

(13) **Surface Pressure**		YES	NO
q) Is the lowest surface pressure 24 hrs previous to the Estimated Time of Outbreak (ETO) ≤ 1010.2mb?	q)		
r) If answer to 4(d1) is sfc trough (non-prefrontal) then are the maximum pressure falls between ETO and previous 12hrs ≥ 1.27?	r)		
s) If answer to 4(d1) is a sfc trough or squall line then does 6hrs prior to ETO show pressures ≤ 1009.8mb?	s)		
t) If answer to 4(d1) is a prefrontal trough or cold front then does 6hr prior to ETO show pressures ≤ 1012.0mb?	t)		
(14) **Surface Dewpoint Temperature**			
u) 6 hrs prior to ETO is SfcDew ≥23.5°C?	u)		

If answered YES to 2 or more of the above then issue a **SEVERE WEATHER WARNING!!!**

Remarks:

Figure 1 (cont'd)

*5) Surface temperature: The thermal air structure must be conditionally unstable. The magnitude of the temperature is important in two ways.

i) It controls the ability of the air to hold and transport moisture.

ii) It affects the Wet Bulb Zero (WBZ). This will be expounded upon further in the literature. The most vigorous storms take place in air having a subsidence type inversion, a characteristic associated with wind shear.

6) Stability indices: The stability of the air column is dependent in large part on the low level moisture and temperature distribution.

g) K-Index- combines both moisture and stability parameters into a single index.

K.I.= (850mb Temp - 500mb Temp) +
(850 mb Dew Point) - (700mb
Dew Point Spread)

Values of K.I. 30.0 or greater indicate a greater than 60% likelihood of thunderstorm activity.

h) Lifted Index (L.I.)- obtained from the mean moisture in the lower 3000ft of the sounding. More negative values indicate increasing instability.

7) Wind shear: Most severe weather results from self-perpetuating convective systems and a certain minimum value of vertical wind shear is necessary in order to sustain the relative low level inflow into such systems. The greater the vertical wind shear between the low level and 500mb the higher the potential for severe thunderstorm development. Shear also affects the strength of the updrafts which in turn has an effect on the size of hailstones or even the generation of such a phenomenon

If the vertical wind shear extends through the middle of the storm (≈4-6 km) the rotation dynamically induces a pressure deficit which is strongest several kilometres above ground and thus produces a vertical pressure gradient that accelerates surface air upward. (3)

i) Directional shear- pronounced veering (30 ° or greater) between the low and mid level winds is desirable. The greater the directional shear between these levels the more certain the development of severe activity.

8) 500mb 24hr height change: This parameter is associated with the temperature changes at 500mb and with the 500mb vorticity field. Height falls provide valuable clues as to the location and movement of short and longwave troughs in the middle atmosphere. Higher thickness values are associated with cold air advection associated with the passage of a cold front.

*9) Low level moisture: k) This is best determined by taking the mean relative humidity of the lower 3000ft of the sounding. l) Another indicator would be the average of the 850mb and surface dew point temperatures. Large amounts of moisture are needed in the boundary layer to support updraft growth.(2) Weisman and Klemp

10) 1000-500mb thickness: Increasing thickness values indicate low level warm advection and an expansion of the air column. compensating for this expansion is near surface convergence.

13) Surface pressure: The surface pressure is termed a delimiting parameter in the sense that as it rises the likelihood of severe outbreaks is reduced. It is also

indicative of the magnitude of the low level convergence field and associated vertical motions.

q)Maximum 24hr pressure change: Taken over the previous 12 hr period the 24hr surface pressure tendency reflect important changes aloft. Also the falls aid in predicting the rate of change of low level moisture and heat.

There are some other important and relevant parameters which need to be added to this list. However, these at the time of the research could not be easily computed. Technological and computational advancements have now made these parameters readily available. These include

1) Convective Available Potential Energy (CAPE):This parameter is related to the buoyancy of a parcel of the air after attaining a height equivalent to the Level of Free Convection (LFC). It is proportional to the positive area on a sounding. The larger the value the more buoyant the parcel.

2) Vertical Motion (Omega): The magnitude of the vertical motion yields and approximation to the surface convergence field. Forecasts of increases in vertical motion is directly related to increasing convective activity. Deep convection is generally limited to those areas where the vertical motion fields indicate upward motion of $-3x10^2$ mb/sec.(4) Johns et al.

3) Height of Wet Bulb Zero (WBZ): This is the height in the environment sounding of the wet bulb intersection with the 0°C isotherm on the Skew-T chart. It is assumed that this is an indicator of the height of the freezing level in a storm column that might develop in the air mass. Destructive winds in squall lines and airmass thunderstorms are dependent on the downward surge of strong wind currents aloft, the temperature difference between the downdraft and environment air and the forward component of the storm. It approximates the height of the freezing level of the downdraft air within which hailsones are likely to be.The higher this level is above ground the longer the melting process can operate.

The reason for the non-inclusion of the above three parameters was that this work was initiated before the acquisition of the present communication facility i.e. STAR IV. Now the capability exists for the generation of these forecast variables. As more severe weather events unfold critical values will be obtained for these parameters while the importance of other variables already included in the worksheet will be reviewed.

4) Conclusions and Implications

With the identification of key indicators to a severe local storm outbreak came a systematic method of forecasting for such events. These signatures were displayed in tabular form and as each unfolded a check mark is placed in the appropriate columns in the table.

With the use of this worksheet a severe weather warning system was initiated prior to the dry season of 1996. The procedures for its dissemination is that after a certain number of key indicators were identified then a severe local storm **watch** would be issued. If however there is visual evidence of an outbreak either by satellite imagery or radar. Even if an individual calls in such information via telephone or some other medium then a severe local storm **warning** will immediately be issued. If none of the above had occurred then the forecaster would continue to fill in the remainder of the worksheet.

The forecasting of maximum wind gusts is done by the use of an empirical formula as described by Fawbush and Miller 1954 (5). The other method is graphical and takes into account the downrush temperature of the air.

Due to the localised nature of severe storm events a difficulty arises in pinpointing exact localities for such an outbreak. Therefore in Belize whenever watches/warnings are issued they cover the entire country.

END

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