Low Level Easterly Wind Surges (LLEWS): an initiator of coastal precipitation in Belize

Dennis S. Gonguez
Meteorologist
Synoptic Section
Belize Weather Bureau

Abstract

Pulses in the mean easterly flow have long been a phenomenon which serve as an instigator of showery outbreaks along coastal Belize. The study embarked upon here served to show whether through a process of isolation such surges not only exist, but are also capable of generating enough shear vorticity to initiate or even perpetuate coastal shower activity. The total wind vector of a rawinsonde sounding profile up to approximately 10 000ft was resolved into its two components. A 24hr east-west velocity component change was observed. A critical or threshold value for this u-component (or more appropriately –u since it is the east-west component) change above which convection was initiated was determined.

1. Introduction

Occasionally outbreaks of precipitation occur in the absence of any obvious synoptic nor mesoscale weather patterns over Belize. Sequences of satellite imageries at this time also rule out the possibility of advection of showers over the region. A forecaster having relinquished his post at the end of his duty shift leaves contented cherishing the thought that no major deterioration in conditions can be expected in the next day or so. Six to twelve hours later a much-unanticipated outbreak occurs drenching major sections of coastal areas. In retrospect the forecaster discovers that there had been substantial increase in the mean surface to 700mb wind. He or she then attributes this increase in shower activity to the apparent strengthening of the low-level flow. The development of such pulses after a while become a 'crutch' for the explanation of any unaccounted outbreak. The common adage becomes "It occurred because of the wind max."

This research is an attempt to assign numerical values critical to this sudden change in wind speeds which initiates some forms of coastal precipitation. After removing all synoptic and mesoscale type features as forecast parameters then easterly pulses can be looked on as a possible initiator of showers.

This paper was concocted entertaining the notion that the reader would have had some competency and educational background in meteorological analysis and interpretation. However, other readers not so well versed can readily grasp the basic concepts and follow through logically as each step in the analysis procedure is presented.

The first section deals with the kinematics governing the generation of vertical spin-up as related to strong wind shear in a unidirectional flow regime. Following this is a section dealing with the reasons for using an easterly component of the total wind in diagnosing the effects of these pulses. Actual methodology involved in the analysis and synthesis of results is addressed in the next section. The fourth section deals with the results based on a case by case basis and concludes with a direct comparison showing similarities or lack thereof between the individual cases.

Though this research was not geared for operational use further investigation could render the conclusions applicable to the development of some operational technique.

2. Overview of Shear Vorticity Generation.

The presence of pulses in the mean flow generates rotation/circulation through the production of shear vorticity. Consider now a flow as depicted in Figure 1 where the lengths of the arrows are indicative of the magnitude of the wind speeds.

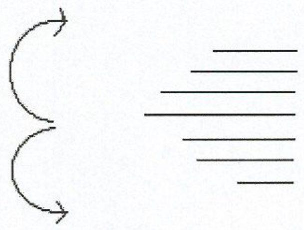

Figure 1

The vertical component of vorticity denoted by

$$\zeta = (\partial v/\partial x) - (\partial u/\partial y) \qquad \text{eqtn(1)}$$

is representative of the local spin-up of the horizontal winds about a vertical axis. (ζ is representative of the relative vorticity, u and v the perpendicular components of the total wind vector and x and y, two of the three axes in a three-dimensional Cartesian frame of reference.)

The vertical spin-up is related to vertical motions and is impacted by a gradient in wind speed or lateral shear. For laterally sheared flow in this research the term $\partial v/\partial x = 0$ in eqtn(1) and vorticity generation is entirely due to $\partial u/\partial y$ i.e. the shear in u-component of the total wind vector. This is the term, which was investigated throughout this research. The presence of pulses in the mean easterly flow generates circulation through this shear vorticity term.

3. Topographic and Seasonal Effects

During the months of March through May the prevailing southeasterly airflow maintains arid conditions through much of this period. A Fohn effect is generated by the downslope winds on the lee side of the mountains in neighbouring Honduras. As a consequence this eliminates both southerly winds and the dry season from this study.

October to March marks the cool season in Belize. Occasionally during this period the region experiences cold frontal intrusions from the higher latitudes. The thermodynamic stability of such air masses renders the cold northerly and northwesterly winds useless as related to an investigation of surges in the mean flow. However, in between frontal passages the airstream would retain a prominent easterly component, which provides opportune intervals for observation and analysis of surging easterlies.

With the breakdown of the winter pattern of zonal flow aloft (300 and 200mb) comes the advent of the rainy season in late May or early June. Interactions of low level tropical waves with upper atmospheric vortices and troughs account for much of the precipitation at this time. Interspersed between and readily discernible again are pulses in the easterlies, which do account for a portion, though small, of the rainfall accumulation observed in this season.

It is these well-separated occurrences of surges, which provide substantial 6-8hr rainfall amounts along some coastal areas of Belize.

4. Method

There were six cases under investigation. These cases were selected based on the absence of any major synoptic nor mesoscale features and also the unexplained occurrence of precipitation in the absence of such features. Another criterion used in selecting cases was the observance of a notable strengthening in the near surface flow.

Winds from the 1 000-10 000ft level at intervals of a 1 000ft were resolved into their south-north (v) and west-east components. These components were calculated using $u = -\mathbf{V}\times(\sin\beta)$ and $v = \mathbf{V}\times(\cos\beta)$ where **V** represents the magnitude of the observed wind speed and β the direction from which **V** is blowing. If β was such that $180° \leq \beta \leq 360°$ then **V** was treated as a non-applicable parameter. The +u-component were also not utilised since the are representative of wind blowing from off the land and hence a more stable airstream in most instances.

Consider eqtn (1) and putting the v-comp equal to zero. For an easterly flow component the u-comp would have a negative value. Then eqtn (1) becomes

$$\zeta = -(\partial u/\partial y)$$

And for a 24hr u-comp (Δu) change this last equation now becomes

$$\zeta = -[\partial(\Delta u)/\partial y] \_\_\_\_\_\_\_ \text{eqtn}(2)$$

To be labelled a surge (Δu) > some observed threshold value.

U-comp winds were subtracted from the previous day's yielding a 24hr-speed change(Δu). A profile of this Δu was then plotted and the maximum magnitude and location of this change was noted. Lower threshold values for this change were found. These values reveal the minimum change in the u-comp (along with the level) which would be required to generate enough shear vorticity to trigger coastal showery outbreak.

5. Case Studies

Case(1): Dec 14-15 1994

Synopsis:

The 13 and the 14th of December, 1994 were rather uneventful days with generally fair conditions prevailing. However, conditions changed dramatically on the night of the 14th through the early morning hours of the following day. The weather became cloudy and showery over the east central portions of the country. Heavy downpours were so intense that some streets in Belize City were flooded from the overnight rains. In retrospect forecasters attributed this event to a surge in the mean easterly flow.

Some rainfall figures revealed that at Saint John's College in Belize City 29.5mm of rainfall fell- this was after a day with no measurable rainfall amounts. 7.5mm occurred at the International Airport and 17.2mm at the Punta Gorda station, which would lie on the outer fringes of the main affected area. These were accumulated following dry days with precipitation amounts close to a trace at some stations.

The plot below of a vertical profile of Δu-comp showed that the maximum speed change was experienced just near the 3 000ft level.

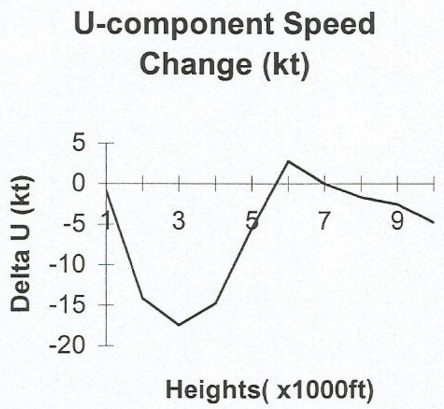

Figure 2

The magnitude of this change was some 17.5kt.

Case (2): 27-28th August 1995
Synopsis;

Although a tropical wave made its way across the region on the 27th the weather was mainly fair. A southeasterly flow prevailed at low levels while there were no significant features aloft. The following day this tropical wave was too far away to have an influence on local weather conditions. However, that morning skies became cloudy with outbreaks of showers and thundershowers.

A 1009mb surface low pressure was centred near 14°N 86°W at 1200 UTC. Since the showers first started in the early morning hours this low-pressure system could not have singly been responsible for these outbreaks since an additional lifting mechanism would have been required.

Figure 3 below shows the profile of the 24hr wind surge for the morning of the 28th.

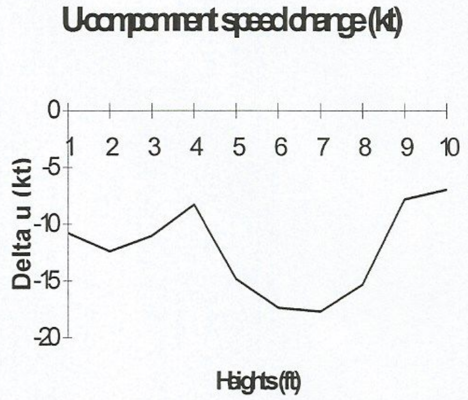

Figure 3

The maximum Δu occurred near the 6 500ft with a secondary maximum at about 2 200ft. The magnitude of this secondary maximum is approximately 12kt.

Wet and unsettled conditions affected most coastal regions during this scenario. Coastal stations such as Punta Gorda reported 115mm on the 28th, Rum Point- 63mm, Savannah- 50mm and St. John's College 25mm after a day of no rainfall.

Other Cases:

Several other cases were examined which due to space constraints can not be elaborated upon. These cases do show that there is some correlation between this 24hr u-component change and the initiation of precipitation. A threshold value for this change turned out to be 9.85kt at approximately 3 000ft.

Although this research was not geared to be used in operational forecasting it proves that that such surges do exist and are capable, through the generation of shear vorticity, of initiating precipitation. So weather forecasters should be aware of its existence.

END