4A.2 CONVECTIVE HAZARDS ASSESSMENT PROCESS: REVISED RICKS INDEX

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ABSTRACT

A technique initially developed in 1986 to estimate convective threats based on observed and forecast upper air soundings has been refined and tested in an operational setting since 1992. This technique scales expected convective weather outcomes based on the pressure difference between the freezing level and the midpoint of a parcel's Convectively Available Positive Energy. The output has been empirically scaled from 0 to 216, with values exceeding 150 indicating severe thunderstorms are likely. Routine application of this method has shown it to be successful, primarily by increasing situational awareness of potential hazardous weather situations. Computer software has been developed to facilitate the computation of the likelihood of other severe weather parameters, including convective wind gusts, heavy rainfall potential, expected hail size, and tornado intensity.

Since 2004, software has been configured to analyze forecast soundings from the National Center for Environmental Prediction's (NCEP's) North American Mesoscale Model. The output is a variety of weather parameters, similar to the operational model output statistics, but also includes the convective hazards parameters. The software has been recently modified to also analyze forecast soundings from the NCEP's Global Forecast System. Evaluation of the performance of the process has revealed some benefits, but also some obstacles in automating the computations. The computation and interpretation of the Ricks Index will be demonstrated, and some applications and verification data will be shown. Examples of the output statistics, operational strategies and plans for future development will also be presented to demonstrate a total convective hazards assessment process.

1. INTRODUCTION

1.1 Origins of Ricks Index

In 1986, a basic investigative study was undertaken to determine the behavior of Gulf of Mexico sea breeze convection along the Florida panhandle coast. The intensity and propagation of sea breeze convection was empirically correlated to various thermodynamic and convective indices, as well as combinations of temperature, dew point, and equivalent potential temperature at several atmospheric pressure levels. A measure was sought that 1) could easily be computed from a thermodynamic diagram, 2) could adequately correlate to the convective integrity of a sounding, and 3) could be scaled quantitatively and qualitatively. The measure that was found to have the highest correlation was the convective "risk index". This was measured by computing the algebraic average of the pressure of the level of free convection (LFC) and the pressure of the equilibrium level (EL) to derive the positive area midpoint (PAM), in millibars. This value was subtracted from the pressure of the freezing level to produce a convective "risk index". It was noted that convective severity increased as this convective risk index increased in value. The index was dubbed the "Ricks Index" by colleagues that used the results in forecast operations.

1.2 Precipitation Calculator

In 1991, this study and findings were applied to an operational forecasting routine in Jackson, Mississippi, by computing the index with daily upper air soundings and cataloging outcome and associated weather affects. A computation for quantitative precipitation forecast (QPF) was derived by algebraically combining the pressure

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levels of a sounding's wet bulb zero, the freezing level, and the zero degrees Celsius crossing of a lifted parcel's pseudo-adiabat to represent a net pressure term in a modified hydrostatic equation. This equation would incorporate the Ricks Index value as the convective parameterization of the calculations to indicate a potential quantitative precipitation forecast. Initial research and application of this methodology was first presented in October 1992 at the National Weather Service 3rd Heavy Precipitation Workshop in Pittsburgh, Pennsylvania (Ricks, 1993). A series of PC based programs and scripts were written to facilitate the computation of the Ricks Index and corresponding weather expectations for a particular sounding. This first program was called the Precipitation Calculator v1.0, written in BASIC, in 1991. This was simply an input-output form that a user supplied necessary input from a worksheet. The program required fifteen elements that had to be obtained from a sounding. Version 2.0 of the Precipitation Calculator was upgraded to Q-BASIC in the mid 1990s and included more functionality, but still required input of approximately ten elements obtained from a sounding. In May 2005, the program was transposed into Tcl/Tk 8.2.3 for a more contemporary graphical user interface (GUI), aptly named Precipitation Calculator v3.0. While the methodology still required worksheet type input from the user, the output was more robust and refined for operational situational awareness leading up to a convective weather event; inclusive of a new Hail-VIL relationship that scaled expected hail sizes with a comparable WSR-88D Doppler Weather Radar detected Vertically Integrated Liquid (VIL). Many applications since the technique's inception have shown favorable results.

1.3 Convective Hazards Assessment Program (CHAP)

Feedback from users that have applied the methodology suggested a desire for less user input and more automation. This prompted the development of a Tcl/Tk script that could affectively ingest BUFKIT (Mahoney and Niziol, 1997) BUFR format soundings from conventional numerical weather models. Output would be displayed via meteograms and time series plots for the various convective elements (expected tornado strength, expected hail size, expected convective gusts, probability of severe thunderstorms, short-term QPF, potential QPF, and the hail-VIL correlation). By August 2007, a script was written to accomplish this requirement and it was named the *Convective Hazards Assessment Program* (CHAP). Its display capabilities also include conventional index calculations derived within the BUFR files (Lifted Index, K-Index, Showalter Index, precipitable water, etc.). It is the intent of this paper to detail the computation of the Ricks Index, its relationship to convective weather outcomes, verification of several cases with examples of successful application and a general overview of the CHAP program functionality.

2. RICKS INDEX CALCULATIONS

2.1 Definitions

Following conventional parcel theory principles, a parcel of air lifted dry adiabatically from the surface or from a low altitude until saturated will become buoyant and will continue to lift moist-adiabatically if the parcel's temperature remains warmer than its surrounding ambient temperature. The quantity measured by the integrated difference of the parcel's temperature along a moist adiabat to that of its ambient temperature at each pressure level during its ascent is defined as the Convectively Available Potential Energy (CAPE, with units Joules per kilogram). Research has shown this value to be significant for determining severe weather potential, but the same research indicates weak correlation of a particular CAPE value to direct expected outcomes. (Craven et. al., 2002, Blanchard, 1998). However, if one were to quantify the displacement of CAPE from a reference point, a correlation can be applied to qualify the value to expected convective outcomes.

The Ricks Index accomplishes this by measuring the midpoint of a lifted parcel's CAPE from the sounding's freezing level, by algebraically averaging the pressure of the Level of Free Convection (LFC) and the Equilibrium level (EL), in millibars. This resulting value is defined as the Positive Area Midpoint (PAM).

$$PAM = 0.5\,(P_{LFC} + P_{EL}) \qquad (1)$$

The PAM is then subtracted from the pressure of the freezing level to result in the Ricks Index (RI). Technically, the units are in millibars, but often indicated as unitless. Schematically, RI is shown in figure 1.

$$RI = P_{FZL} - P_{PAM} \qquad (2)$$

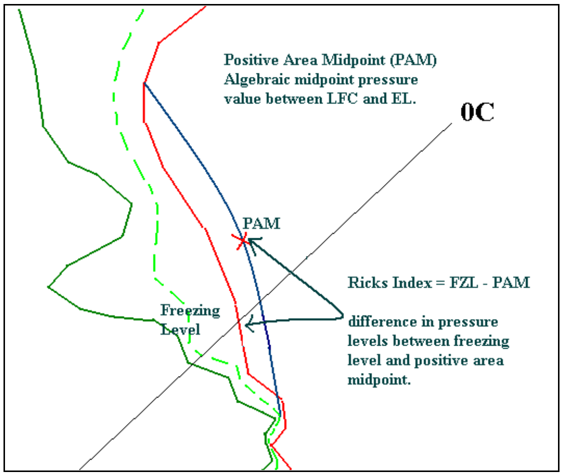

Figure 1. Schematic Skew-T, log P diagram showing the calculation of Ricks Index.

By definition, the RI is only applied if the freezing level is within the bounds of the CAPE (e.g. between the LFC and the EL). A systematic false alarm will result if this condition is not adhered.

2.2 Scaling – simple regression analysis

A linear equation was determined to best represent the probability of precipitation (PoP), whereby

$$\text{PoP (\%)} = 0.5\ \text{RI} - 17 \qquad (3)$$

Severe thunderstorms were empirically found to occur whenever RI > 150 with a 50 percent or greater chance of occurrence. Minor singular aspects of severe thunderstorms (i.e. hail without damaging winds) were sometimes indicated at values from 134 to 150, and typically precluded any severe thunderstorm affects below values of 110. A linear equation for probability of severe thunderstorms (PoSVR) was derived as

$$\text{PoSVR} = \text{RI} - 110 \qquad (4)$$

This is shown graphically in Figure 2. Many cases of severe thunderstorms were grouped into bins of severity, either by magnitude of wind gusts, reportable hail sizes, or reported tornadoes. These cases were matched to a computed RI from the nearest temporal and spatial sounding. Best-fit curves were then applied to each convective element versus RI, and are shown as

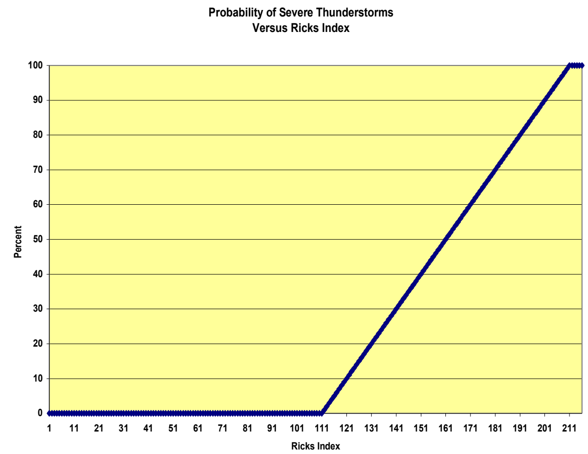

Figure 2. Probability of Severe Thunderstorms versus Ricks Index from equation (4).

$$\text{Convective gusts (knots)} = 0.5\ \text{RI} - 17.5 \qquad (5)$$

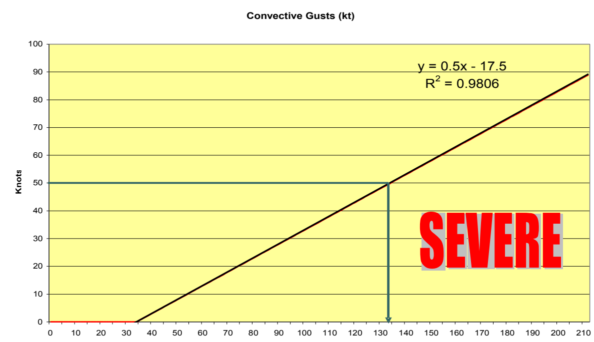

Figure 3. Convective Gusts vs. Ricks Index from equation (5).

Reportable Hail Size (HS, inches) is denoted as

$$\begin{aligned}\text{HS} = {} & 7\text{exp-12}(\text{RI})^5 + 1\text{exp-09}(\text{RI})^4 - 1\text{exp-07}(\text{RI})^3 \\ & + 6\text{exp-06}(\text{RI})^2 - 0.0001(\text{RI}) + 0.0008 \qquad (6)\end{aligned}$$

whereby small non-severe sized hail is indicated with values ranging from 100 to 139. Severe sized hail with diameters larger than 1.9 cm (0.75 inches) is indicated for RI values greater than 140. The correlation of the hail sizes to probability of severe thunderstorms sets a 40 percent chance of verifying large hail near 2.54 cm (1.0 inch) diameter at RI = 150 (Figure 4).

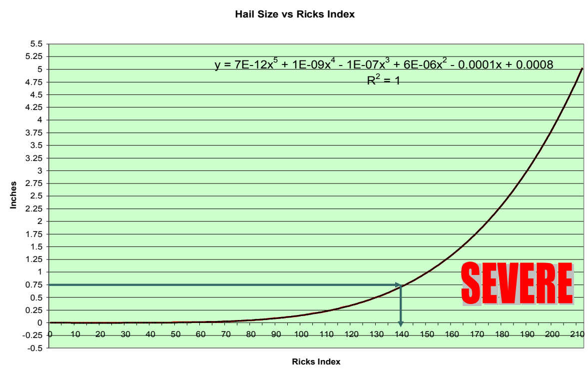

Figure 4. Hail Size vs. Ricks Index from equation (6).

The RI – Tornado relationship was originally determined to be a step equation by rounding a linear equation to the nearest integer for the Fujita tornado intensity scale (Fujita, 1981) versus RI (Figure 5) and shown as

$$\text{Tornado (Fujita)} = \text{round}\ (0.0713\ \text{RI} - 9.4973) \qquad (7)$$

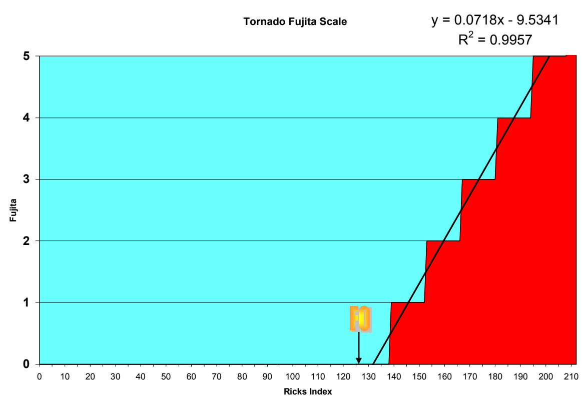

Figure 5. Tornado intensity vs. Ricks Index computed for Fujita Scale from equation (7).

Since February 2, 2007, the National Weather Service officially implemented the Enhanced Fujita (EF) tornado intensity scale, which modified the classification of tornado impacts based on a three second averaged peak wind (Texas Tech U, 2006). A polynomial best fit curve was produced to correlate RI to a 3 second wind scale, which was then categorized into the equivalent EF rating, (Figure 6) and shown mathematically as

$$\text{Tornado (EF)} = 3\text{exp-}08(\text{RI})^{4} + 6\text{exp-}07(\text{RI})^{3} + 0.0043(\text{RI})^{2} - 0.0746\ (\text{RI}) - 0.2914 \qquad (8)$$

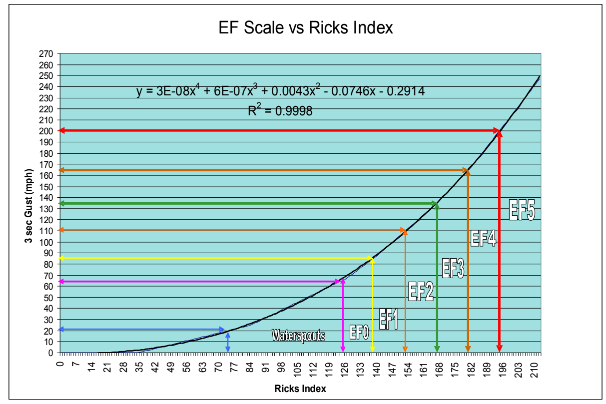

Figure 6. Enhanced Fujita (EF) Scale vs. Ricks Index computed from equation (8). This correlates a 3-second wind gust to the EF scale.

At a RI value of 150, there is a 40 percent chance of verifying a tornado with an EF-1 rating. Land- and water-spout types vortices have been observed with RI values as low as 84, but preclude any super-cellular produced tornadoes. EF-0 tornadoes have resulted in values starting at 125, and incrementally increase to EF-5 intensity at RI = 195. This higher threshold has aligned well with NOAA Storm Prediction Center declarations of a Particularly Dangerous Situation (PDS) event, whereby the most extreme convective phenomena are likely to occur or a large scale organized severe thunderstorm outbreak is anticipated.

Precipitation computations, as noted above, utilize a modified hydrostatic equation of the form dP = -rho g dZ, but by replacing the density of air, rho, with that of water, rho_w, and weighting the equation with a mixing ratio, omega. The mixing ratio term is the residual mixing ratio determined by taking the mean of the wet-bulb zero degree mixing ratio and the pseudo-adiabat zero degree mixing ratio from the applied lift, and subtracting the mean value from the saturated mixing ratio at the freezing level. The final QPF equation takes the form

$$dZ\ (\text{inches}) = (dP * \text{omega} * LC) / 253.285 \qquad (9)$$

whereby dP is the combination of two pressure departures from the sounding, the thermal term: pressure of freezing level (P1) – pressure of pseudo-adiabat zero level (P2), and the moisture term: P2 – pressure of wet bulb zero (P3). The dP term is then indicated as

$$dP = (P1 - P2) - (P2 - P3) \qquad (10)$$

LC is a logarithmic correction that is necessary for small dP results, indicated as

$$LC = \ln dP / \ln 100 \qquad (11)$$

The constant 283.285 is the product of the density of water (1000 Kg m^{-3}), acceleration due to gravity, g (9.81 m sec^{-2}), a thermal constant, k (0.98371) and MKS to BE unit conversion (0.0254 m in^{-1}).

By negating the residual mixing ratio, and computing strictly for the mean mixing ratio of the P2 and P3 terms, one acquires a cell based precipitation value from equation (9). This assumes the computed rainfall amount will occur along a storm track from one convective cell. If one adds the RI value for that particular lift into equation (9), then a potential precipitation amount is computed, which is considered the maximum amount of rainfall a cell can produce, assuming all of the convective process goes into producing rainfall, also called the 'static' precipitation.

2.3 Verification

In the summer of 2007, a verification study was undertaken by Shawn O'Neil* on randomly selected cases from a period 2002 through 2007, inclusive of large impact events, menial events, marginal cases, and null cases. The methodology was applied often in situ or post-event situations to determine skill in the technique. National Weather Service metrics were used to verify Probability of Detection (POD), False Alarm Rate (FAR), and Critical Success Index (CSI) (NWS Directives, 2007 and Schaefer, 1990) collectively for any verifiable severe local thunderstorm output, and individually for tornado, damaging wind, large hail, and heavy precipitation. The source of verification for tornadoes, damaging wind and large hail was the NOAA Storm Prediction Center event archives (*www.spc.noaa.gov*) and the NOAA National Climatic Data Center *Storm Data* publications (*www.ncdc.noaa.gov*). Heavy precipitation was verified using the NOAA River Forecast Center stage IV processed rainfall graphics acquired from the NOAA hydrology web page (*http://water.weather.gov*), for those events that were archived within their dataset. Table 1 provides verification statistics for this study.

2.3.1 Damaging Wind

There were 33 wind events within the 46 randomly selected trials. Of the 33 events, 17 were correctly indicated, 5 did not verify, and 11 were under-forecast (unwarned). This produced a POD 0.607, a FAR 0.227 and a CSI 0.515 for wind events.

2.3.2 Hail

Hail events with diameters larger than 0.75 inches, totaled 31, of which 15 were correctly indicated, 7 did not verify and 9 were unwarned. This resulted in a POD of 0.625, a FAR of 0.318, and a CSI of 0.484 for hail events.

2.3.3 Tornado

Tornado cases numbered 31, with 19 correctly indicated, 12 not verified and 0 unwarned. This produced a POD 1.000, a FAR 0.387, and a CSI 0.613 for tornado events. Not included in the computations was one case whereby a waterspout potential was indicated and a waterspout was reported within the sampling set.

2.3.4 Any Severe

Of the sampling set, 35 cases had at least one report of some form of severe weather, though many of the cases had multiple reports of various degrees and intensities. Among the 35 qualifiers, 23 verified, 5 did not verify and 7 were unwarned. This resulted in a POD 0.767, a FAR 0.179 and a CSI 0.657.

3. RAW OUTPUT STATISTICS

A local modeling effort to improve conventional numerical model output statistics has led to a capability to compute the Ricks Index relationships within a model domain. The Raw Output Statistics (ROS) model is generated by ingesting Bufkit BUFR format model data for the NAM or GFS into a Perl script written by forecaster Timothy Erickson. While ROS generates conventional meteorological output statistics (i.e. temperature, dew point, probability of precipitation, etc.) with locally adapted equations, it can also be formatted to compute locally derived variables and decision tree type algorithms. The resulting digital matrix appears similar to typical MOS output formatting, offering a familiar and flexible option for forecasters to view the data, or incorporating into established MOS ingest protocols.

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STUDYROS5 TERICK KNEW 120716
BTR   ETA ROS GUIDANCE  02/12/2007  0000UTC
WKDY        MON                 TUE                        WED                        THU
DATE   /FEB   12            /FEB   13                   /FEB   14                   /FEB   15
HOUR      03 06 09 12 15 18 21 00 03 06 09 12 15 18 21 00 03 06 09 12 15 18 21 00 03 06 09 12
MNMX               47( 47)     70( 70)     57( 47)     72( 72)     39( 37)     47( 47)     31
TEMP      52 49 47 47 58 66 70 65 60 58 58 61 67 71 72 59 50 47 43 39 41 43 47 41 39 37 34 31
DWPT      43 45 45 46 52 56 58 56 55 54 56 61 63 63 60 48 40 38 34 30 27 28 29 28 27 26 23 20
WCHL      49 46 44 47 56 66 70 64 58 55 56 59 66 71 72 56 45 40 35 30 32 35 42 35 31 30 26 22
CLDS      O6 CL S5 O6 B1 S2 S2 B4 S^ B2 O1 B1 O1 O1 O2 CL CL O3 O3 O3 O2 S3 CL O> O9 B8 S8 CL
CLHT      56 NA 47 57 14 22 21 35 22 19 15 10 14 12 21 NA NA 26 26 26 24 28 NA 11 93 79 79 NA
TMPO      43    43 05          25    10 05 00 05             22 22 22 22          88 67
TTSK      OV CL PC OV MC PC PC MC PC OV OV OV OV OV OV CL CL OV OV OV OV PC CL OV OV OV PC CL
VSBY      P6 P6 03 P6 P6 P6 P6 P6 P6 P6 03 <Q P6 P6 P6 P6 P6 P6 P6 P6 P6 P6 P6 P6 P6 P6 P6 P6
OBVS            BR                      BR FG
TYPF            SF                      AF RF
WDIR      11 13 11 11 13 14 14 13 14 14 16 17 21 24 27 30 32 33 34 35 36 36 35 35 35 36 36 36
WSPD      07 07 06 00 09 14 16 15 11 11 11 13 11 14 17 16 16 17 17 16 16 14 14 10 13 11 10 10
GUST      08 08 07 00 19 16 20 18 13 13 13 15 22 17 19 20 19 20 21 19 19 16 16 12 14 13 11 11
PP06          8     0     5    24     0    35     7     0     0     0     0     0    21     0
PP12                8          24          35           7           0           0          21
TTPP      00 00 00 00 00 00 00 00 00 00 01 01 02 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00
RQPF      TR 00 00 00 00 TR TR 02 00 00 00 04 05 00 00 00 00 00 00 00 00 00 00 00 00 TR 00 00
TOTR               00          02          04          05          00          00          00
PTYP                                    RA RA RA

FIRE WEATHER PARAMETERS:  ETASEM16.0  ETASEF52.496
HOUR      03 06 09 12 15 18 21 00 03 06 09 12 15 18 21 00 03 06 09 12 15 18 21 00 03 06 09 12
HMXMN            ( 96%)      ( 61%)      ( 99%)      ( 66%)      ( 73%)      ( 49%)      ( 67%)
SFCRH     71 85 91 95 82 71 65 73 83 88 94 99 88 74 66 68 68 71 70 70 58 55 49 61 63 62 64 65
MIXHT     06 06 06 06 23 71106 10 10 19 14 10 19 78117103 46101100 90 81 90 90 82 74 74 22 50 MTR
TPRTD     11 13 12 12 14 14 15 14 14 15 16 18 21 24 27 31 33 34 35 35 36 36 35 36 36 36 36 25
TPRTS     04 04 04 04 06 06 08 07 06 07 07 06 07 08 09 10 09 10 09 09 08 06 06 07 08 08 07 08 M/S
VENTN     03 03 02 02 13 45 83 07 06 13 09 07 13 64104106 43 97 93 78 65 56 56 58 61 60 14 40
CATDY      1  1  1  1  1  3  4  1  1  1  1  1  1  3  4  4  3  4  4  3  3  3  3  3  3  3  1  2
STAGX      3  3  3  3  3  2  2  2  2  2  0  0  2  2  2  2  2  2  2  2  2  2  2  2  2  2  3  3

INTERGOVERNMENTAL USE ONLY...-00MET60.SITE
2MTP      50 48 46 46 58 68 70 64 59 58 58 61 65 69 70 60 52 47 43 39 38 43 46 41 39 38 35 32
SKTP      47 45 44 44 63 76 74 60 56 58 58 60 66 73 74 59 49 47 43 40 45 55 53 38 39 38 32 30
BLTP      55 52 53 54 56 64 69 68 61 57 59 60 63 66 68 62 55 48 45 41 36 38 43 43 39 38 36 33
RIHL      00 00 00 00 00 00 00 00 00 00 00 00 00 01 01 00 00 00 00 00 00 00 00 00 00 00 00 00 INCH
RICG      00 00 00 00 00 00 00 17 00 00 36 50 53 68 68 00 00 00 17 16 21 22 00 00 00 00 00 00 KNTS
RITN      NA NA NA NA NA NA NA NA NA NA NA NA NA F2 NA NA NA NA NA NA NA NA NA NA NA NA NA NA Fscl
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Figure 7. ROS output for Baton Rouge, LA from 0000UTC 12 February 2007 NAM cycle. The output indicated a F2 tornado potential 32 hours in advance of the actual event in the forecast area.

3.1 An example – February 13, 2007 New Orleans, Louisiana

The WFO New Orleans/Baton Rouge forecasters make use of the ROS output in an experimental operational mode, running concurrent with conventional model output statistics (Ricks and Koziara, 2007). A slight risk severe thunderstorm outlook issued by the NCEP Storm Prediction Center valid for the night of February 12, 2007, through early morning February 13, 2007, prompted an assessment of the convective situation leading into the anticipated event. The ROS output generated with input for the Baton Rouge, Louisiana (KBTR) NAM model sounding (Figure 7) indicated a potential for EF2 tornadoes and severe thunderstorm wind gusts of 30.4 m s^{-1} (59 knots or 68 mph) for the afternoon hours of February 13, 2007. Forecaster discretion correctly placed the greater risk to be sooner than model indicated timing, and the threat would exist for a short window of opportunity during the nocturnal hours. The result was a pair of EF 2 rated tornadoes that moved across portions of the greater New Orleans, Louisiana metropolitan area around 2:30 a.m. CST, causing extensive damage to a hotel in Westwego, one fatality in the Pontchartrain Park section of eastern New Orleans, and 14 injuries. It is believed this may be the first documented case of a tornado event being accurately indicated by operational numerical modeling.

4. CHAP OVERVIEW

The Convective Hazards Assessment Program (CHAP) is a graphical user interface (GUI) approach to viewing Ricks Index based forecast elements for convective processes. The program is a script written in open sourced Toolkit Command Language (Tcl), Toolkit extension (Tk), commonly called Tcl/Tk (pronounced “tickle – tee kay”), using version 8.2.3 (Sastry and Sastry, 1999). The graphing capabilities are accomplished with the use of the BLT version 2.4 extension to Tcl/Tk (Howlett, 2002).

Application of the CHAP script allows a user to obtain BUFR formatted model soundings from either a Bufkit supported sight (i.e. Penn State U., select NWS field locations), or from an ftp obtained method that routinely collects a set of soundings through cron jobs or timed scripts. The program can be applied to the Global Forecast System (GFS), North American Model (NAM, formerly ETA), and Rapid Update Cycle (RUC) models. While the capability exist to run the CHAP output to the maximum allowable time step for each model, the GFS and NAM are set by default to only view output through 48 hours, due to large model solution uncertainties beyond 48 hours. The RUC is viewable through the entire 10 hour available time steps. Once BUFR sounding data are ingested into the GUI environment, a series of seventeen (17) X-Y graphs are generated (Figure 8).The program is designed to provide a quick view of individual forecast convective elements, such as expected probability of precipitation, probability of severe thunderstorms, expected tornado intensity, expected convective gusts, expected hail size, and QPF. In addition, conventional model derived indices of Lifted Index, K Index, Showalter Index, Total-Totals, SWEAT index and Bulk Richardson Number are graphed for quick reference. The remaining graphics are complementary elements to assist in the warning decision making and situational awareness process, such as surface and LCL equivalent potential temperature, the pressure levels for LCL, LFC, EL, FZL and PAM used to determine the Ricks Index for each time step, precipitable water, and the pressure levels used for the QPF computations. In addition to graphics, each element includes an information dialogue box to indicate time step data or advice for interpreting the graph.

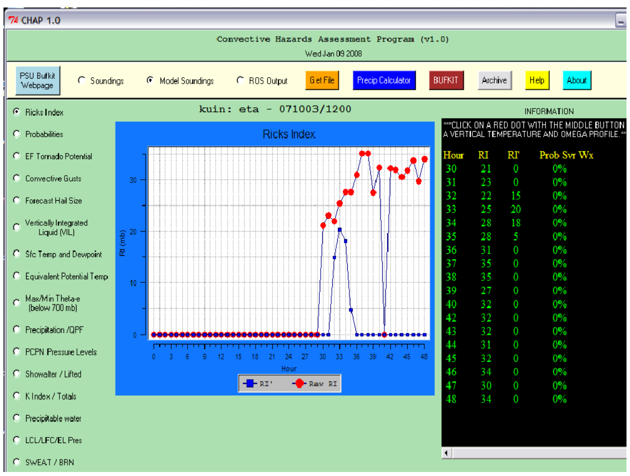

Figure 8. CHAP interface illustrating the layout of the selection elements, the graph viewing area and information text box.

4.1 Functionality

Much of the CHAP output becomes obvious once a user is exposed to the program and becomes familiar with its utility. There are, however, a few unique conditions that are applied to the process that require further explanation.

4.1.1 Raw RI and RI’

Raw RI is computed from the fundamental equation (2) without regard to any negative inhibition areas that may underlie the CAPE. It is assumed that the conditions and expectations attached to the CAPE would be ideally realized, despite any negative affects. Ricks Index prime, RI’, accounts for negative inhibition by subtracting the negative inhibition layer (defined as the departure of the LCL pressure and the LFC pressure) from the CAPE for a net RI. This value is then used to determine the probability of occurrence. Graphically, this is shown as a red trace for RI raw, with this value applied to expected outcomes, and a blue trace for RI’, this value applied to probability of expected outcome. Logically, it would follow that as the blue trace approaches or becomes co-incidental with the red trace; there is an increased probability of realizing the expected impacts, thereby offering a measure of confidence into the forecast. This is effectively shown in Figure 8.

4.1.2 Hail Size and VIL

Hail size is empirically derived from equation (6) above. A means of equating the expected hail size to a corresponding Vertically Integrated Liquid (VIL) value was sought, as this is a popular approach to severe thunderstorm detection of large hail used by NWS field offices. A previous study by Wilken (1994) in Arkansas correlated severe sized hail to 500 HPa temperatures. This scatter plot approach, known as the Arkansas VIL, is utilized by several NWS offices for routine severe weather operations. The linear best-fit equation for the Arkansas VIL is

$$\text{Arkansas VIL} = 2.32 * (T_{500} + 34) \qquad (12)$$

The CHAP method accomplishes a Hail-VIL relationship by determining the CAPE thickness attributed to the applied lift and dividing by acceleration of gravity (9.81 m s^{-2}), shown mathematically as

$$\text{VIL (kg m}^{-2}\text{)} = (P_{LFC} - P_{EL}) / 9.81 \qquad (13)$$

While this equation is highly idealized and simple, it does assume the entire CAPE layer can be sampled adequately by WSR-88D surveillance. In reality, this is rarely the case. If the user of this application maintains this assumption and accounts for sampling limitations, one can approximate an applicable VIL value attributed to producing an expected hail size. Perhaps strength of the CHAP methodology is in determining the minimum expected VIL value for severe hail detection, similar to the Arkansas VIL. This is what is demonstrated in the Vertically Integrated Liquid (VIL) graphic and accompanying information box (Figure 9).

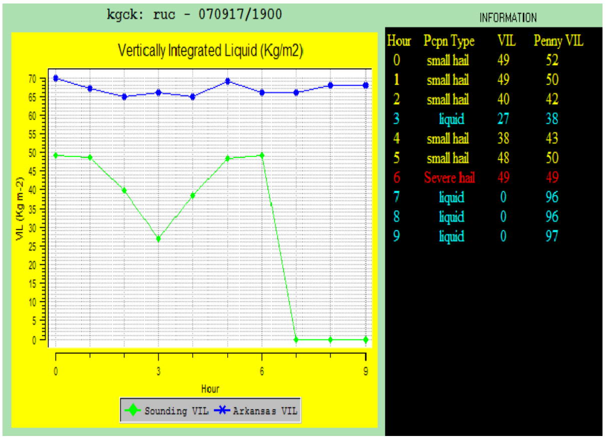

Figure 9. VIL output from CHAP with Arkansas method VIL (blue trace) and Ricks Index method VIL (green trace) and corresponding information text.

4.1.3 LFC, EL, and FZL pressure levels

The Ricks Index, though slowly gaining popularity, remains novel to most severe weather forecasters and researchers. The “LFC, EL and FZL pressure levels” radio button instantly graphs the input levels utilized by the RI computation. This graphic (Figure 10) is intended to show the contributions of the LFC and EL placements in the model domain. The resultant PAM trace can be compared to the FZL trace to indicate temporal changes taking place with a particular CAPE to produce a severe weather expectation. The user is encouraged to routinely view this graphic to determine how a particular CAPE and expected outcomes are derived.

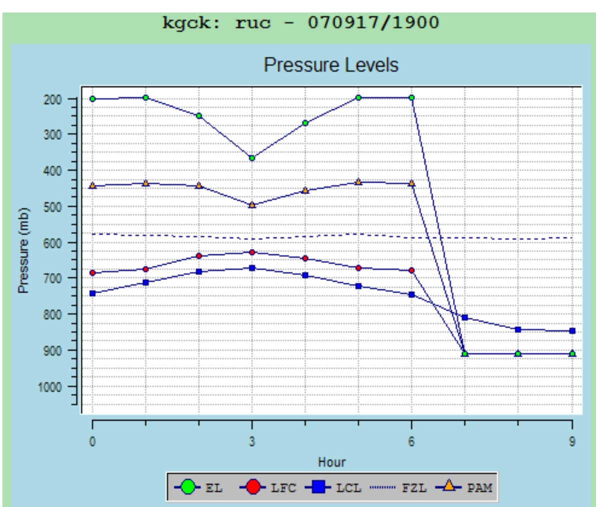

Figure 10. Pressure levels graphic used to compute RI each model time step.

4.1.4 Graphic Zoom

There is a capability in the BLT generated graphics to zoom tighter into the data plots, simply by dragging a rectangle with the right mouse button across the area of interest. This will zoom into the data and automatically adjust the X and Y scales to fit the new viewing area. This is particularly useful when longer range model outputs (i.e. NAM and GFS) are used, improving the visual resolution of the traces.

4.2 An early verification case – RUC model for Garden City, Kansas, September 19, 2007

During the script development and testing of CHAP, a marginally severe thunderstorm expectation was noted in western Kansas on September 19, 2007. The NOAA Storm Prediction Center indicated a ‘Slight Risk’ of severe weather in northern Kansas, extending into central Minnesota (Figure 11). The RUC model was obtained for forecast location Garden City, Kansas for the 1900 UTC model cycle. The CHAP graphics indicated a 34 percent chance of severe thunderstorms (Figure 12), with the primary threat being damaging winds ranging from 25 to 31 m s^{-1} (50 to 62 knots) (Figure 13). Other threats included a small one hour window for severe sized hail near 1.91 cm (0.75 inch) diameter with a projected VIL value of 49 kg m^{-2} (Figure 14). Marble sized (1.27 cm, 0.50 inch) hail was the most likely diameter to be expected. Local Storm Reports from the Dodge City, Kansas Forecast Office indicated two damaging wind reports from the Hill City, Kansas area around 2250 UTC, with a measured gust of 25 m s^{-1} (50 knots or 58 mph) and damage to a store front [www.spc.noaa.gov]. One large hail report was received from the Leoti, Kansas area and several non-severe marble hail reports accompanied the severe weather reports.

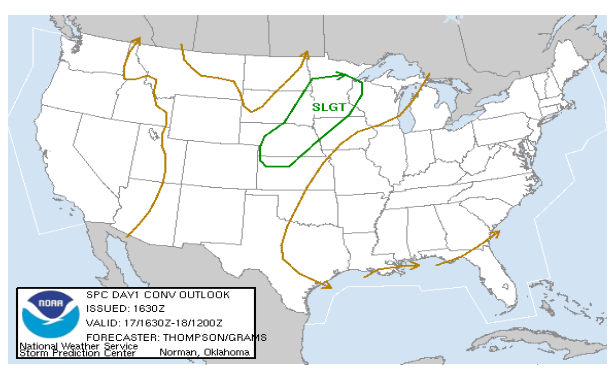

Figure 11. NCEP Storm Prediction Center Day 1 Outlook for 17 September 2007.

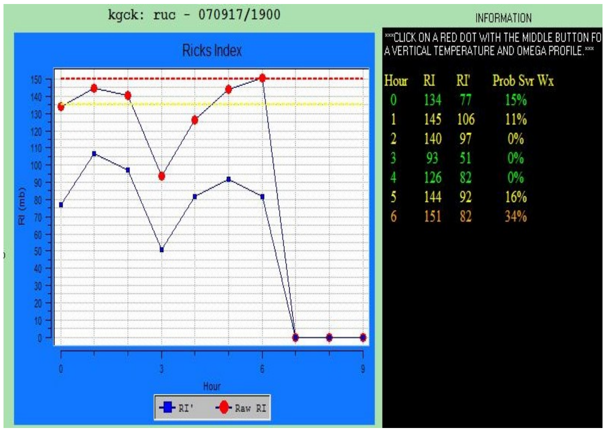

Figure 12. CHAP output for Garden City, KS RUC model for 1900UTC cycle, 17 September 2007. Note the probability of severe weather 34 percent on forecast hour 6 valid 0100 UTC.

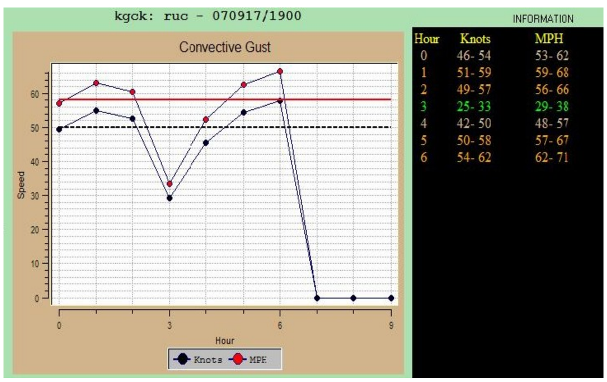

Figure 13. CHAP output for Garden City, KS RUC model for 1900UTC, 17 September 2007.

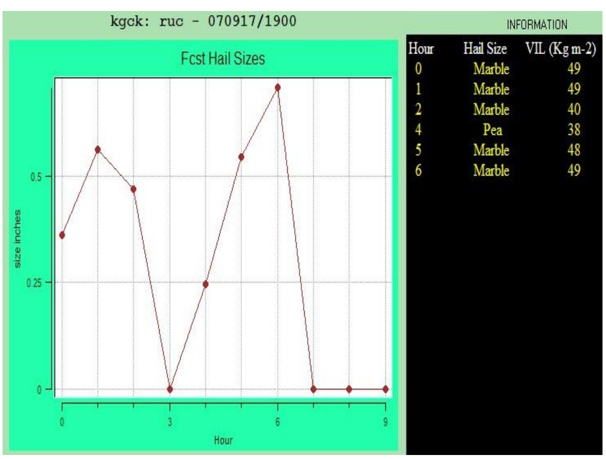

Figure 14. CHAP output for forecast hail size with most likely hail size noted in the information box.

5. SUMMARY AND FUTURE CONSIDERATIONS

The Convective Hazards Assessment Program (CHAP) is a software package that assists forecasters in the situational awareness and severe weather monitoring process. It utilizes the equations and relationships derived from the Ricks Index methodology developed and applied in NWS operations since 1992. Erickson developed a Raw Output Statistics (ROS) model that utilizes locally derived formulae to generate a MOS-like digital matrix output. The ROS model includes the Ricks Index math for indicating convective expectations and precipitation within its computations. Early application of the ROS output successfully indicated an EF 2 tornado event in the New Orleans, Louisiana area on February 12-13, 2007.

Future considerations for further development of this project include a scripting of the program into Java, to satisfy a National Weather Service information technology mandate for summer 2008. One potential benefit of Java scripting will be the capability of providing a web-based interface for academia, private sector and public sector use. It is desired that a spectral analysis of a sounding be achieved to determine a range of expected outcomes for a given range of attainable theta-e values from a sounding. Also, the ROS dataset will be provided graphically via meteograms and time-series plots for visual interpretation.

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Statistic	Wind	Hail	Tornado	All Severe
Number of cases	33	31	31	35
Cases correct	17	15	19	23
Cases not verified	5	7	12	5
Cases unwarned	11	9	0	7
POD	0.607	0.625	1.000	0.767
FAR	0.227	0.318	0.387	0.179
CSI	0.515	0.484	0.613	0.657

Table 1. Verification Statistics from 46 randomly selected cases from about 300 available applications of the Ricks Index methodology. The sampling set ranged from 2002 – 2007 and from various locations in the continental United States east of the Rockies. Qualifiers were only events that forecasted at least one severe element (n = 46).

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