JP3.1 AN INTEGRATED THREE-DIMENSIONAL OBJECTIVE ANALYSIS SCHEME IN USE AT THE STORM PREDICTION CENTER

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1. INTRODUCTION

Real-time observations have always been one of the most important data sets for the forecasters at the Storm Prediction Center (SPC), formerly the National Severe Storms Forecast Center (NSSFC). Historically, these data were plotted by hand and subjectively analyzed. Once modern computer systems were introduced into the operational forecast environment, objectively analyzed grid point fields began to be produced for the meteorologists. Today, a wide variety of objectively analyzed fields are computed and routinely used each hour by SPC meteorologists.

2. HISTORY

Objective analysis programs at the NSSFC using surface observations allowed data from irregularly-spaced locations to be analyzed to a set of equally spaced grid points. In addition to common gridded meteorological fields of temperature, moisture, plus u and v wind components, other derived fields were computed from hourly gridded surface data. Fields such as moisture flux convergence and surface lifted parcel temperatures (Hales and Doswell 1982) were some of the first derived fields.

The addition of objectively analyzed 500 mb temperature fields allowed for the computation of Lifted Indices (LIs) (Galway 1956) by subtracting surface lifted parcel temperatures (lifted to 500 mb) from a 500 mb gridded temperature field. Initially, these indices were from a gridded analysis field produced from the most recent 00 or 12 UTC upper-air data. Even though the surface temperature and moisture were updated by hourly data, the “static” upper-air temperatures sometimes resulted in unrealistic LI values by mid-afternoon. Simple schemes by which the 500 mb temperature field was “updated” by advecting the 500 mb temperatures over a specified time period, while representing an improvement over the static 500 mb temperatures, were not able to take into account temperature changes produced by vertical motion.

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The next step in the evolution of gridded hourly surface and other derived fields was to update the “static” and/or “advected” upper-air temperatures through the use of model forecast data. Gridded 6-hourly forecast fields (interpolated to the current hour) of the 500 mb temperature became available by the late 1980s, replacing the “advective” temperature fields. These hourly Lifted Indices became increasingly important to the forecaster as and the coarse 6 hour time increments changed to hourly forecast 500 mb temperatures.

When gridded upper-air model forecasts (initially at 50 mb increments and later at 25 mb in the vertical) became available, more complex fields such as the Convective Available Potential Energy (CAPE) and Convective Inhibition (CIN) were calculated operationally for the first time using surface lifted parcels. However, except for the CAPE calculations and Lifted Indices which did rely on hourly forecast temperatures aloft, the hourly objective analyses produced at NSSFC remained essentially a surface analysis.

3. CHANGES IN METHODOLOGY

By the start of 1997, the NSSFC (now the SPC) forecast operations were transferred to Norman. The operational forecast computer system changed from the Man-computer Interactive Data Access System (McIDAS) to the National Center AWIPS system (NAWIPS). NAWIPS core software was based on the GEneralized Meteorological PAcKage (GEMPAK- desJardins et al 1991). GEMPAK allows the ability to easily compute a wide variety of meteorological parameters at the surface and/or aloft. The change-over from the McIDAS system to the NAWIPS was occurring during the time the Rapid Update Cycle 2 (RUC 2-Benjamin et al 1998) began producing hourly analyses and forecasts.

4. THE DEVELOPMENT OF “SFCOA”

The current operational objective analysis program at the SPC (which has traditionally been called SFCOA for SurFaCe Objective Analysis) initially began as a GEMPAK based, 2-pass Barnes objective analysis of the surface data. Compared to the older McIDAS based objective analysis (also a Barnes analysis), it differs substantially in that it uses the short-term forecast from the RUC 2, surface fields (temperature, humidity, pressure, u, and v wind components) as a "first guess" for the objective analysis. The RUC 2 forecast fields, in addition to supplying a first quess for the objective analysis, aid in the analysis by filling in data void areas both inland and off-shore. The RUC 2 data are also used as a quality control measure. Observations that depart significantly from these guess fields are excluded from the analysis.

Initially, the SFCOA program calculated basic surface fields such as temperature, moisture and wind and derived surface fields such as moisture flux convergence plus three variations of 500 mb LIs. These three 500 mb LIs were computed by differencing the current surface lifted parcel temperature with (1) the static 500 mb temperature, (2) the hourly forecast 500 mb temperature from the Eta point forecast soundings, and (3) the RUC 2 forecast 500 mb temperatures. However, with the exception of the 500 mb LIs, the SFCOA program had not yet expanded to include other upper-air data.

With the implementation of the RUC 2 in 1998, hourly gridded upper-air data fields were operationally available for the first time. The data sets assimilated in the 40-km RUC-2 include:

1) Surface - wind, temperature, dewpoint, altimeter setting.
2) Rawinsonde/dropwindsonde - temperature, height, moisture, wind
3) Aircraft - wind, temperature
4) Profiler and VAD wind profiles
5) high-resolution ascent-descent aircraft reports
6) ship reports
7) GOES integrated precipitable water retrievals
8) SSM/I integrated precipitable water retrievals
9) GOES high-density cloud drift winds
10)Tropical storm dropwindsonde data - reconnaissance

The SFCOA program was changed to merge the surface objective analysis it produced with a forecast field from the RUC 2 data (time matched to the surface data) above the surface. Once the surface objective analysis is complete, the time matched forecast RUC 2 data at 25 mb vertical increments is combined with the surface objective analysis for a three-dimensional "snap-shot" of the atmosphere. This is usually available at about 15 minutes past the top of each hour. With the availability of the three-dimensional data set, derived fields (e.g. convergence/divergence) from any level desired can be calculated.

In addition to the 2-dimensional "horizontal" calculations, the program "builds" the elements of a vertical sounding (with temperature, moisture, u and v wind and vertical motion) every 25 mb in the vertical at every grid point (currently over 17000 grid points at 40 km resolution). Many of the sounding analysis routines used are those from the expanded and updated UNIX version of the SHARP program (Hart and Korotky 1991) called NSHARP. This allows the computation of numerous fields at point sounding locations as well as at all grid points. The results can then be displayed in a two-dimensional plan view and compared to soundings.

While the SFCOA program combines current surface analysis with the one hour forecast aloft, it also has the capability of incorporating WSR-88D VAD winds and profiler winds. The RUC 2 data is still used as the first guess and for quality control purposes for wind data. When special "off-time" soundings are taken at National Weather Service locations (e.g., 18 UTC) , they are incorporated in the RUC 2 analyses and subsequent forecasts. This allows the most current upper-air wind, temperature and moisture data to be used in the SFCOA program.

The resulting gridded output is a high resolution, three-dimensional "pseudo-analysis" of the atmosphere. This gives the SPC forecasters a very good snapshot of thermodynamic and kinematic profiles that is updated every hour. The SFCOA program currently produces over 225 combined surface and upper-air fields which can be grouped into 7 general classes. These are:

1) Upper-level support (e.g., divergence, potential vorticity, ageostrophic wind)
2) U and V wind components, shear terms and storm relative winds
3) Thermodynamics (e.g., CAPE, CIN, LIs)
4)Layer averages of vertical motion (adiabatic/kinematic)
5) Surface data forcing
6) Lower-level forcing (non-surface)
7) Lapse Rates

Since a virtual sounding exists at every grid point, this structure also allows for the calculations of other more sophisticated fields such as those that predict hail size (e.g., Moore and Pino 1990). Finally, forecasters can use the derived fields to develop other algorithms which they can plot hourly. An example of this is the parameter "SIGTOR" (Thompson et al 2002, elsewhere in this volume).

5. EXAMPLES OF COMPUTED FIELDS

The following figures illustrate several of the fields that are available from the SFCOA program. Each hour, SFCOA uses the technique of combining the most current surface objective analysis with the short term (one or two hour) forecast RUC 2 data at 25 mb vertical resolution. Figure. 1 shows the CAPE for the most unstable parcel (as calculated within the lowest 300 mb). When the CAPE is calculated using the 100 mb deep mean layer parcel, Fig. 2 shows a reduction of approximately 500 J/kg in the CAPE at most grid points. Figure 3 illustrates how the surface to 3 km storm relative helicity is displayed hourly using the technique of combining the most current surface analysis with the RUC 2 forecast data. Figure 4 is the Bulk Richardson Number shear.

6. SUMMARY AND CONCLUSIONS

The SFCOA software program has continued to grow and evolve over the past 5 years to meet forecaster needs. It allows for the computation of fields not readily available elsewhere and is not dependent on model specific output fields other than for the basic fields of temperature, moisture, wind and pressure or height. It allows the forecaster to have two dimensional displays of fields that have previously only been available from sounding analysis programs at specific points. Output from the program is available hourly with a complete analysis by approximately 15 minutes past the top of the hour. New parameters can be developed and implemented quickly. Many of the graphics are on the SPC mesoscale analysis web page (http://www.spc.noaa.gov/exper/mesoanalysis).

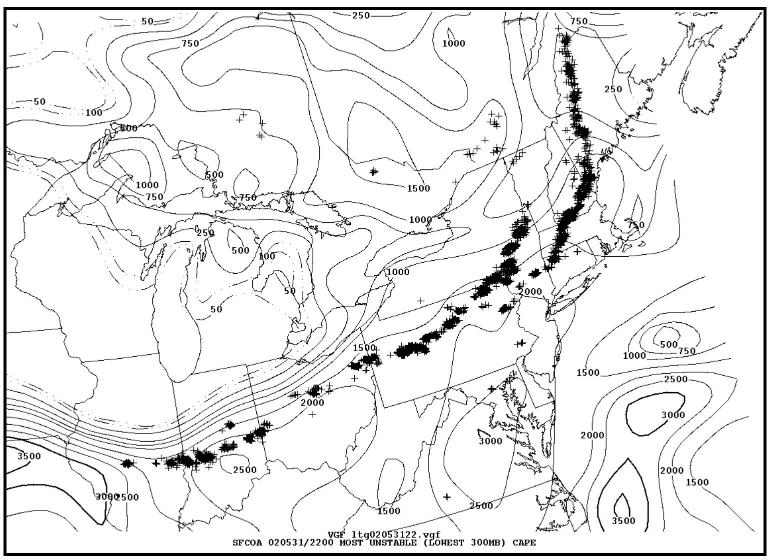

Figure 1. Lightning flashes from 21 to 22 UTC ("+" symbols) on 5/31/02 and most unstable CAPE in lowest 300 mb.

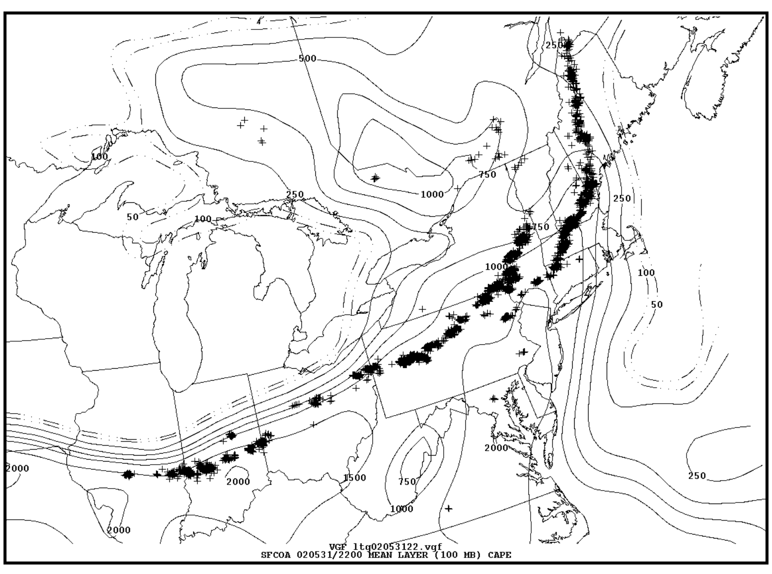

Figure 2. Same as Figure 1 except for mixed layer CAPE (lowest 100 mb) for 5/31/02.

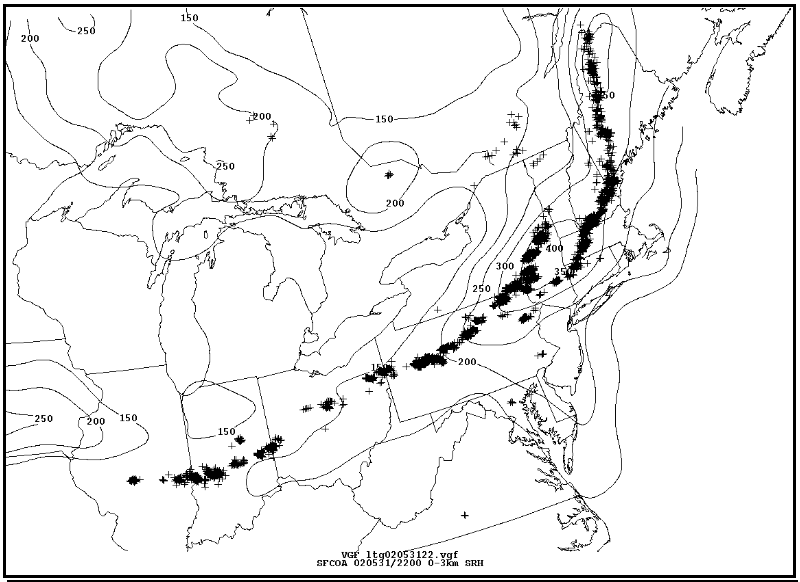

Figure 3. Same as Figure 1 except surface to 3 km storm relative helicity at 22 UTC.

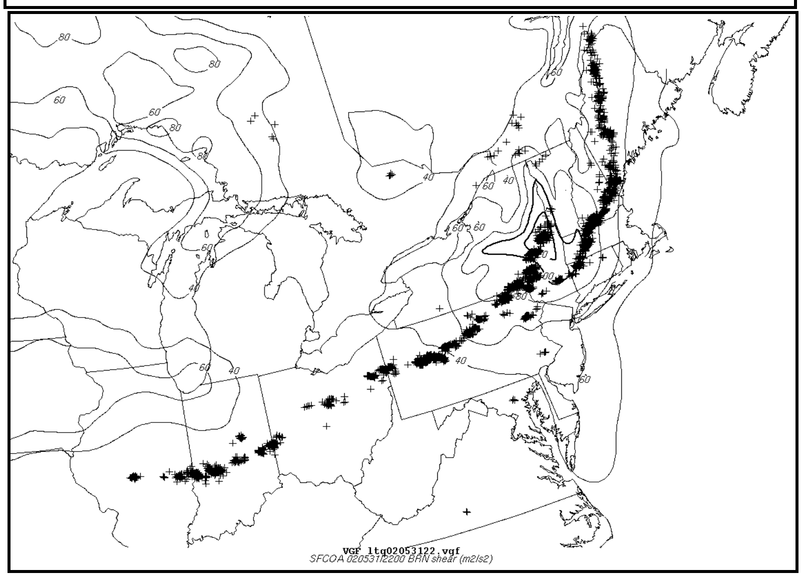

Figure 4. Same as Figure 1 except Bulk Richardson Number (BRN) shear at 22 UTC.

The SFCOA currently produces over 225 fields. Often the forecaster will reference these fields when composing the text discussion of the SPC products. Many of these fields also serve as candidate predictors in an algorithm to predict lightning (Bothwell 2002). Applications are not limited to just severe weather, but winter weather, heavy rainfall, and fire weather as well.

7. REFERENCES

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