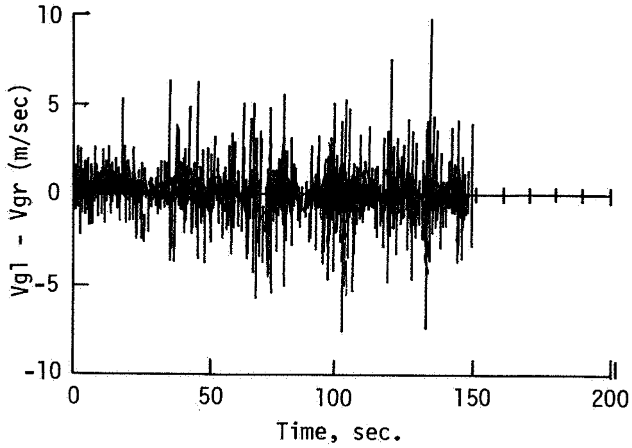


Figure 14. Vgl - Vgr for Run 10.

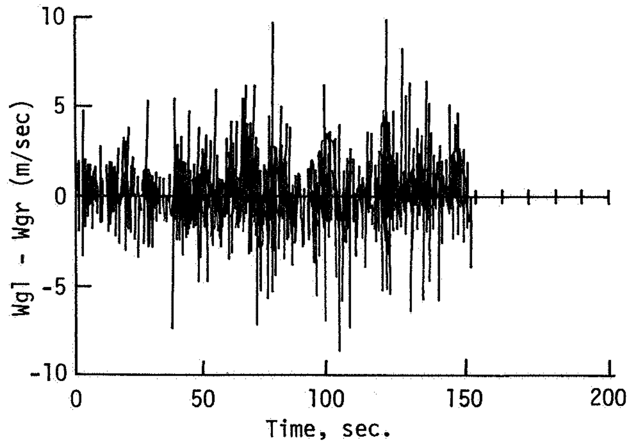


Figure 15. Wgl - Wgr for Run 10.

The last three (3) figures show differences in the longitudinal, lateral and vertical components of velocity. Note the peak velocity differences are 10 m/sec (20 kts) which is quite significant. During these runs, large values (up to 12°) of roll attitudes occurred presumably because of these gradients. Another interesting feature of these figures is the filtering effect of the differencing. Differencing removes large-scale variations which makes a large difference in the probability distributions. While individual velocities have a ragged, multimodal appearance, the densities for the velocity differences have an almost Gaussian appearance.

This concludes my presentation.

# GEM: Statistical Weather Forecasting Procedure

Robert G. Miller

The objective of the GEM Program was to develop a weather forecast guidance system that would:

(1) predict between 0 - 6 hours all elements in the airways observations, that includes: ceiling; visibility; temperature; wind; present weather (such as fog); etc.;

(2) respond instantly to the latest observed conditions of the surface weather, be they special or record observations;

(3) process these observations at local sites on mini-computing equipment, such as the AFOS system;

(4) exceed the accuracy of current persistence predictions at the shortest prediction of one hour and beyond;

(5) exceed the accuracy of current forecast model output statistics inside eight hours; and

(6) be capable of making predictions at one locations for all locations where weather information is available.

GEM, an acronym for Generalized Exponential Markov, fulfills all of these requirements and has the following additional features. It needs only the information contained in the airways observation and requires no model output or surrounding station data; it is a generalized procedure, meaning it can predict anywhere, at any time and for any projection. Also, it can run on anything from a small, hand-held micro-computer such as the TRS-80 on up to the larger models. Since GEM was originally designed to handle observational information at non-standard times and at random locations, it is capable of utilizing observations such as PIREPs.

I would like to now explain about the creation of GEM. There are 41 stations from which data were taken. These are shown in Figure 1 with filled-in circles. The empty circles are the verification stations. Each of the filled-in stations contributed 100,000 observations to a statistical sample totaling 4,100,000. All elements in the observation were included as predictors and predictands. Transformations were made on the original observations producing 290 on/off conditions, yielding over 1 billion bits; and this was reduced to a matrix of 50,000 multivariate regression coefficients from which forecasts were then made. The matrix is used to make a forecast for one hour. This forecast, represented by probabilities of these 290 elements, is fed back as the observation for the second iteration, and this process continues hour by hour until it finally settles down to climatology at some future projection, typically around 24 hours or more. To make the forecast station specific, a simple additive constant is introduced that accounts for the local hourly and monthly climatologies. It has been found by exhaustive experimentation that the equations, themselves, are applicable anywhere. An exponential dampening is imposed to accommodate the continuous time Markov process.

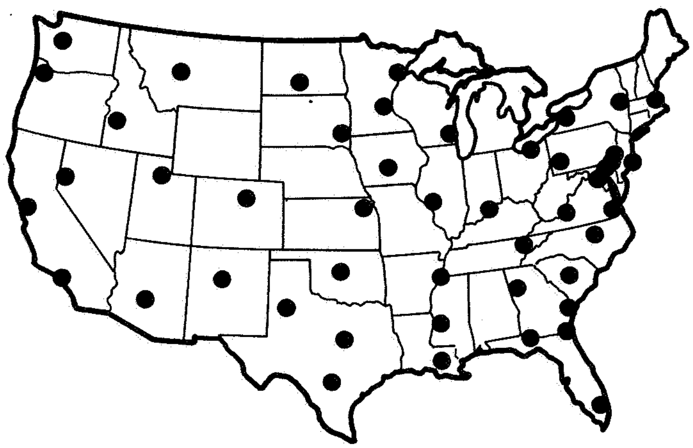

Figure 1. Locations from which composite data were sampled. Filled circles represent the dependent sample stations; while open circles, the independent sample.

Figure 2 shows an example of what a forecast looks like. This is for March 21, 1980. The observation was taken at 7:00 local time for Washington, DC, and its airways observation is indicated on the first row. The temperature was 62° and this represents the mid-point of a five-degree interval. The dew-point depression was 1° and the visibility was six miles, light rain and fog were occurring with the wind direction 170° at 15 knots and so forth. The figure shows also the first and second cloud layers plus the total sky and the ceiling in hundreds of feet. The forecast of the same airways observation is made for three hours, six hours, nine hours and twelve hours. The forecasts for intermediate hours could have been produced, but GEM is limited to 7,000 bytes of the AFOS system with AFOS running. It is interesting to note that the case shown on Figure 2 had a frontal passage around 3100; and, as you can see, the change in the weather characteristics was indicated beginning with light rain showers, a wind shift and the intensification of the wind speed.

In terms of the verification of this sytem on the seven stations in Figure 1, amounting to about 24,000 independent observations, GEM predictions compared against persistence were more accurate, even beginning with the first hour. Anyone who has tried to improve upon persistence at one hour, knows that it is a difficult thing to accomplish. This was judged by analyzing the probabilities and the correct

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 GGG  EEEEE M   M
G     E     MM MM
G GGG EEE   M M M
G   G E     M   M
 GGG  EEEEE M   M
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TECHNIQUES DEVELOPMENT LABORATORY
FOR STATION: DCA
VALID FOR 12 HOURS AFTER MAR 21, 7 LOCAL

| HOUR | ! | TT | DPD | VV | WEATHER | | DDFF | PPP | C1 | H1 | C2 | H2 | TS | CIG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | ! | 62 | 1 | 0600 | R- | F | 1715 | 9976 | BKN | 7 | OVC | 10 | OVC | 7 |
| 10 | ! | 62 | 1 | 0600 | R- | F | 1715 | 9976 | OVC | 5 | OVC | 10 | OVC | 7 |
| 13 | ! | 62 | 1 | 0600 | R- | F | 2615 | 9976 | OVC | 5 | OVC | 10 | OVC | 7 |
| 16 | ! | 62 | 3 | 0400 | R- | RW- F | 2425 | 9976 | OVC | 5 | OVC | 10 | OVC | 7 |
| 19 | ! | 57 | 3 | 0400 | R- | RW- F | 2425 | 9976 | OVC | 5 | OVC | 15 | OVC | 7 |

Figure 2. Minicomputer printout of a sample GEM forecast for March 21, 1980, made at 7:00 A.M. EST for DCA.

number of forecasts of the two procedures, where persistence probabilities were conditioned on the current value of persistence. When compared with MOS, the results showed a cross-over of skill at about eight hours, favoring GEM early and MOS later. We have succeeded in showing that MOS and GEM can be blended together with a resulting increase in skill. Under a GEM-MOS blend, GEM would be inhibited in its versatility to forecast at any hour. Separate sets of equations for the blending would be required to account for all differences between the hour of the day of the GEM input observation and the last available MOS forecast cycle model output time. Requiring this model output would inhibit GEM's versatility. Therefore, this GEM-MOS blend has just been done for experimental purposes.

The details of GEM and the verification results are included in NOAA Technical Report No. 28. Our current plans for GEM are to subject it to a rigorous automation of field operations and service (AFOS) field tests at selected stations. The objective is subsequent use throughout the National Weather Service as objective guidance to cover 0 - 8 hours. We see the principle potential of its application for aviation as part of a local monitoring and updating package on AFOS. In other words, when an observation comes in, the package forecasts whether the terminal forecast is out of bounds, according to the amendment criteria. If necessary, the package will update the forecast with the GEM forecast. It takes about seven seconds to make a forecast like the one shown here.

We expect that this will be integrated into the Aviation Route Forecast system in a unique manner. Specifically, we can provide the predicted airways observation for display and incorporation into the analysis, whether objective or subjective. It could be the basis for predictive capabilities in the automated observation system, AWOS, ALWOS and PROFS. Because of its generalized capabilities, GEM does not require a large historical sample nor a totality of elements. Any subset of these elements can be used. We feel ultimately that GEM will be the basis for the 0 - 6 hour automated terminal forecast.

Questions from the Floor

QUESTION: Do you foresee GEM as part of PROFS?

RESPONSE: Bob Miller

Yes, I went on a trip to Boulder and talked with people that I know are interested in such a versatile system as this.

QUESTION: Are they interested?

RESPONSE: Bob Miller

I would say that they are, but I have yet to have them ask me to come and design the set-up.

QUESTION: You said GEM predicted a frontal passage. How can it do that?

RESPONSE: Bob Miller

Don't ask me how, I don't know. It has gone beyond my wildest dreams. It has the ability to do things like begin precipitation, end it, or even change its type.

## REFERENCE

1981 GEM: A Statistical Weather Forecasting Procedure. NOAA Technical Report NWS-28, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, 103 pp.

# The PROFS FAA CWSU Support Evaluation Project

John W. Hinkelman, Jr.
FAA Rep to PROFS Program
Environmental Research Labs, NOAA

Eighteen months ago I briefed these proceedings on the PROFS Program and our plans and expectations. For those of you who are not familiar, PROFS stands for Prototype Regional Observing and Forecasting Service. PROFS is the top-priority NOAA Research and Development and Systems Integration Program. It is a local or user-scale program concentrating during its first phase on improving metropolitan area (aviation terminal area) services. We're utilizing the newest technologies in weather observation, data analysis and forecasting and information dissemination and integrating these activities together to provide more operationally oriented products to users. The latest capabilities in observations, objective data analysis and short period forecasting are being used concentrating during Phase I on very short-period severe thunderstorm prediction.

This past summer we utilized the NCAR CP-2 Doppler radar jointly with the JAWS Program, along with conventional weather service radars at Limon and Cheyenne, 21 automated observing stations which provide general coverage of the Denver Terminal area and half hourly GOES satellite, visual and IR data. We've also incorporated information from an automatic upper-air sounder, the profiler, taking wind, temperature and humidity observations on a 20-minute basis. By 1983, we will have four profilers operating, covering the state of Colorado.

All of these data are processed in real-time at our Boulder facility on two VAX 780's, one 750 and four PDP 11/24's. Processed data are then displayed at our high-resolution RAMTEK display developmental forecast workstation for forecaster use in preparing operationally-oriented products. From time of ingest of our five-minute data sets to product output, takes less than two minutes. Current storm conditions, expected storm tracks and areas of anticipated severe weather are displayed and disseminated in real-time. We provide two outputs--one to the Denver Forecast Office for public use, and a subset to the Denver ARTCC's Center Weather Service Unit for aviation use. Our Forecast Workstation configuration is very similar to the planned FAA CWSU automated workstation to