A Cursory Glance at Results from NASA's B-57B Gust Gradient Program

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The Gust Gradient Program is summarized in Figure 1. An assumption frequently made in turbulence modeling is that there is no spanwise variation in turbulent gusts. If this assemption were true, an aircraft would not experience rolling and yawing moments. Some turbulence models do simulate gust gradients, but they are accounted for in a theoretical manner (based on Dryden, Von Karman, or other spectral models). These models are questionable at low altitudes in the planetary boundary layer. Virtually no spanwise gust gradient data have been published, and the purpose of the Gust Gradient Program is to fill this gap.

The third part of Figure 1 indicates how the aircraft was flown to obtain data. The B-57B normally will only be flown at locations providing weather radar and preferably Doppler radar. At these sites, it will take off when radar indicates a storm cell within roughly 20 nautical miles of the runway. Data is collected at takeoff and up to an altitude of about 1000m. At that point, the data recorder is shut off and the B-57B approaches the cell as closely as possible and executes a level flyby (where the recorder is again turned on) of the storm in the vicinity of outflows, turbulence, etc., if possible. The plane returns to the runway, executes a touch-and-go and returns to the storm at possibly a different altitude. This cycle continues until the storm cell moves outside a convenient radius, or until the data recorder runs out of magnetic tape. The B-57B endurance is roughly three (3) hours and the recorder holds an hour of tape.

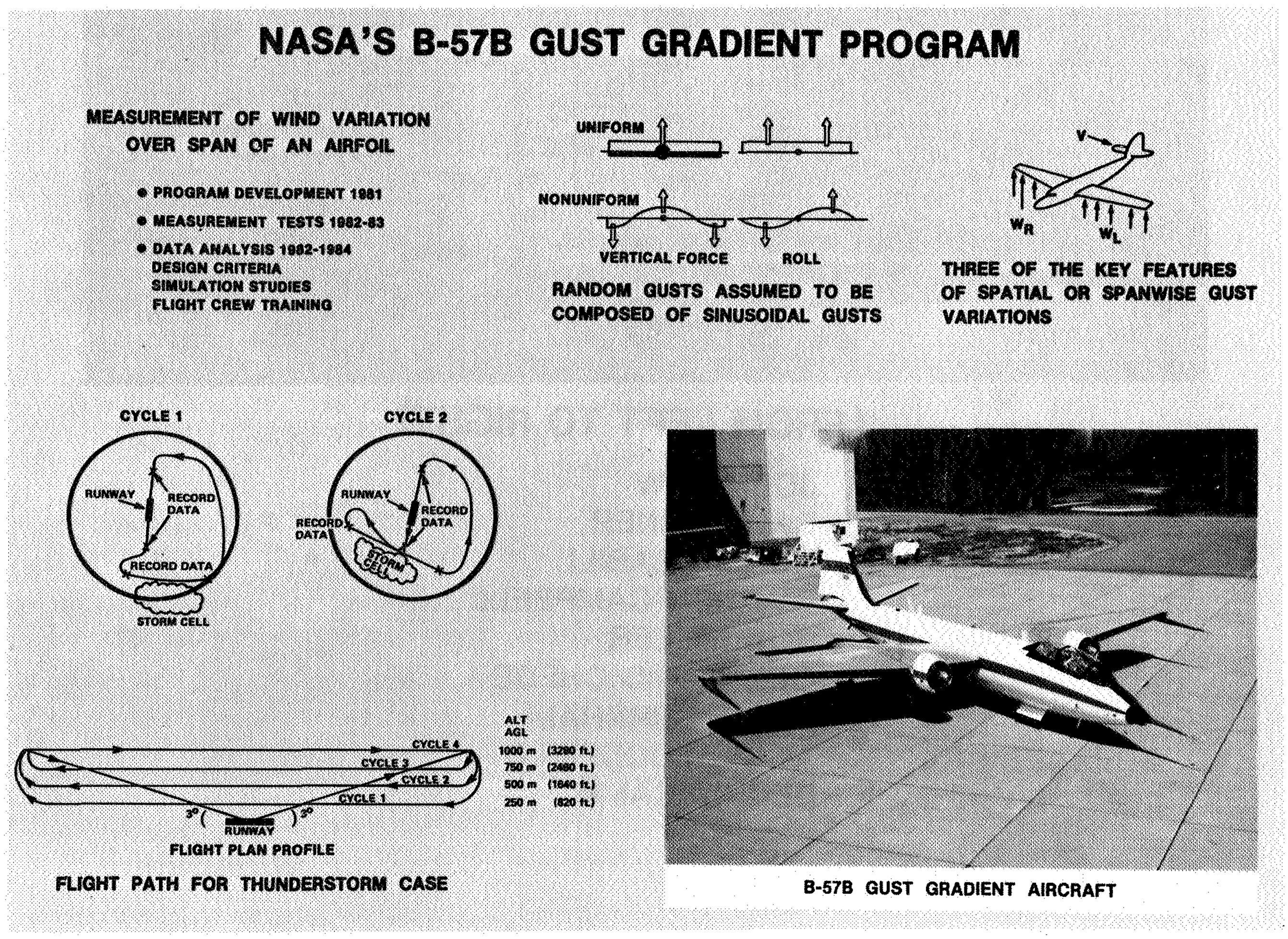

Figure 1. NASA B-57B Gust Gradient Program

Figure 2 shows possible locations for gust gradient flights. These locations include the four NASA Centers involved in the project. Langley Research Center (LaRC) is responsible for instrumentation on the aircraft and for converting voltage values on the data tapes to engineering units. Responsible individuals at LaRC include Hal Murrow and Robert Sleeper. Robert is attending this workshop. MSFC is responsible for data analysis. Responsible individuals at Marshall are Dennis Camp and myself. Dryden is responsible for all flight operations and the aircraft. The project manager at Dryden is Wen Painter. Wen is here at the workshop along with his wife, JoAnn, who helped us during the Joint Airport Weather Studies (JAWS) Project. Ames serves in an advisory capacity and also is responsible for one of the instruments on the aircraft, an IR radiometer. UTSI, through Walt Frost, has been very much involved in planning the overall program and in the data analyses. To date, data flights have been flown at LaRC (checkout), at Denver in conjunction with the JAWS Project and at Dryden. The only really complete data set is from Denver.

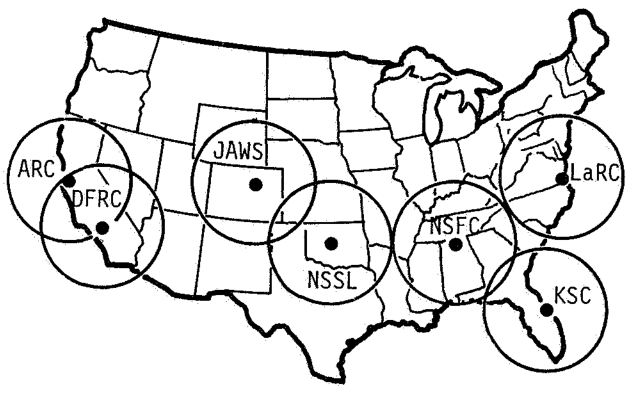

Figure 2. B-57B COVERAGE (100km AND 500km RADII)

The Gust Gradient Program moved to Denver this past summer (1982) from July 7 to July 23, to participate in the JAWS Project. This international program was a data intensive effort involving triple Doppler radar, a surface weather station mesonet and other aircraft. The JAWS area is shown in Figure 3. The center of flight

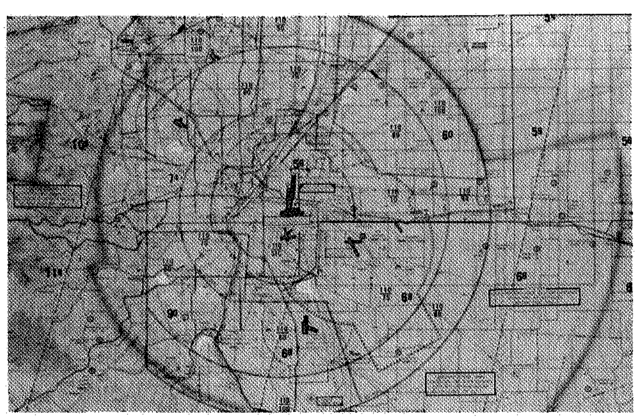

Figure 3. JAWS Area Map

activity was Stapleton airport. The other aircraft in the program flew out of Jeffco and the B-57B flew out of Buckley Air National Guard Base.

Figure 3 depicts the CP-2 site which was operational headquarters for the JAWS Project. Shown is the radome and several trailers, one of which is the operations van. The flight engineer (Dennis Camp or myself) was in the operations van during each test. The test engineer had access to a radar console which indicated weather conditions and aircraft locations. With help from JAWS Project radar meteorologists John McCarthy, Cathy Kessinger, Cindy Mueller or others, the engineer could direct the B-57B to "hot" locations. John and Cathy are attending this workshop.

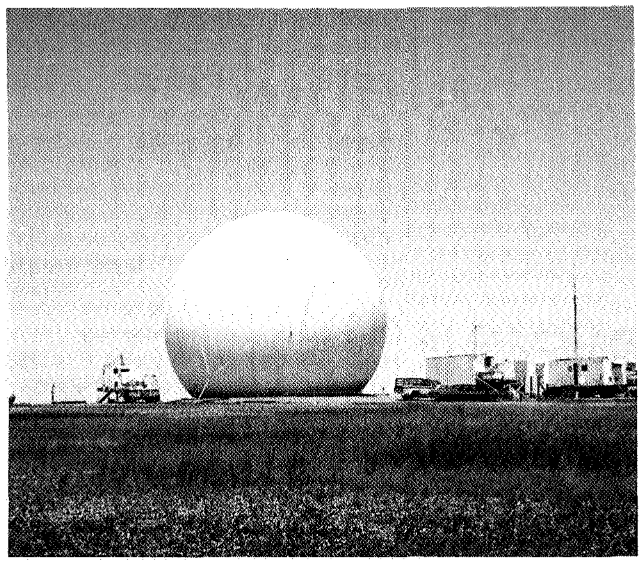

Figure 4. JAWS Operations Center at CP-2

We were extremely fortunate during JAWS in the amount of good nasty weather that occurred. During our time at JAWS, rain, gustfronts, microbursts, tornadoes, funnel clouds and hail occurred within the JAWS network. On July 14, a funnel cloud was sighted at CP-2. Another day, centimeter size hail fell at CP-2 and the noise inside the trailer was enough to disrupt communications with the aircraft.

During JAWS, eleven (11) different flights were made. The test summary is indicated on Figure 5 The B-57B encountered severe turbulence on the three (3) flights of July 14, 15 and 21. The data analysis effort is currently concentrating on these severe cases. Of above-average interest, is Flight 3 on July 9, when the B-57B flew intercomparison tests with the Royal Aircraft Establishment (UK) HS-125 aircraft, and the University of Wyoming King Air. Heading the RAE program is Alan Woodfield who is here and Wayne Sand, also here, piloted the King Air.

FLIGHT	DATE	START	END	COMMENTS
1	7/7	15:41:38	15:59:39	Landmark Familiarization Flight
2	7/8	14:49:11	16:40:35	Light to Moderate Turbulence
3	7/9	13:17:10	15:42:34	Light to Moderate Turbulence with Data Correlation with JAWS 02 and 03
4	7/11	14:46:07	17:02:44	Moderate Turbulence and Lightning
5	7/13	15:20:18	16:44:56	ILS Approaches to Stapleton in Light Turbulence
6	7/14	13:41:13	15:55:21	Severe Turbulence and Outflows Visible on Radar
7	7/15	14:08:13	16:26:20	Outflows, Severe Turbulence, and ILS Approaches
8	7/17	15:49:35	17:17:56	Rain with Light to Moderate Turbulence
9	7/20	15:59:30	18:35:52	Light to Moderate Turbulence with some ILS Approaches
10	7/21	16:05:05	18:04:40	Good Downburst with Moderate to Severe Turbulence
11	7/22	13:36:09	15:24:45	Light and Moderate Turbulence

Figure 5. Gust Gradient Flight During JAWS 1982

Some data from two (2) runs occurring during Flight 7 (July 15) is presented in Figures 6 - 15. Figures 6 - 9 show the altitude traces for Runs 11 - 14. Two of these tests were level flights and two were simulated ILS approaches over open fields. The minimum ordinate is 1.5 km above sea level which is roughly ground level in the Denver area.

Figure 10 shows true airspeed for Run 10 (a straight and level flight). Several sudden rises and drops in airspeed are indicated on this figure which could result from outflow features.

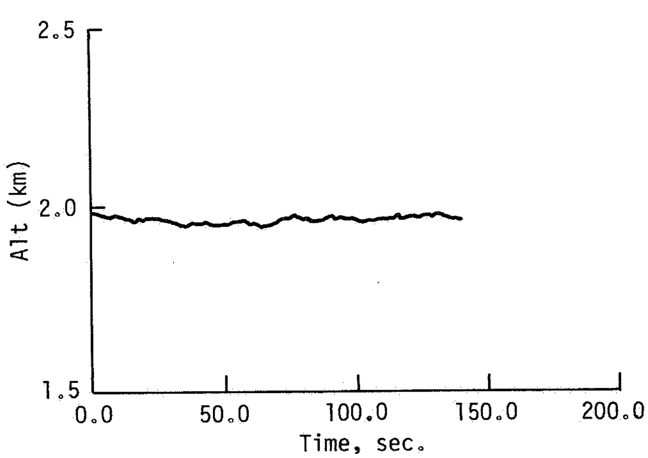

Figure 6. Altitude Trace for Run 11.

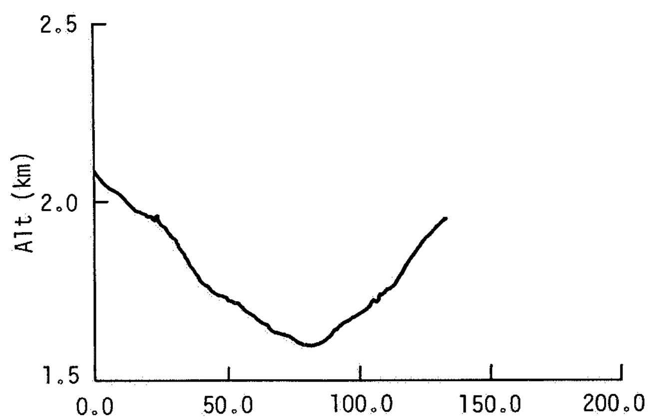

Figure 7. Altitude Trace for Run 12.

Figures 11 and 12 are traces of turbulent velocity measured at the center and right wingtip booms. When overlaid, it can be seen that these traces are very similar, especially in large-scale features. Intuitively, features of a scale larger than the 19.5m (60 ft.) wingspan of the B-57B should show up, simultaneously, in both velocity traces. Smaller scale features contributed to the differences in the two traces. From these two figures, some question arises as

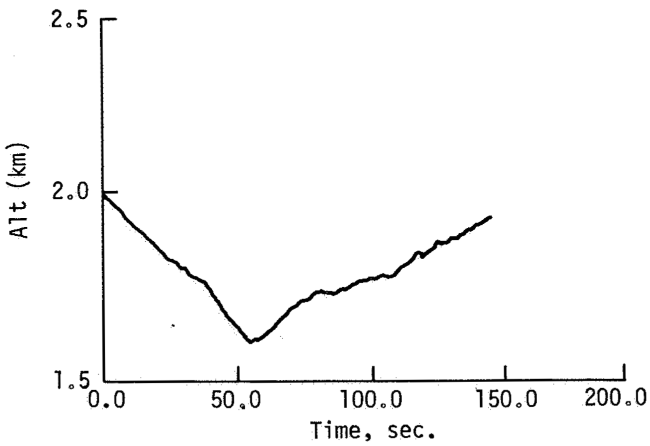

Figure 8. Altitude Trace for Run 13.

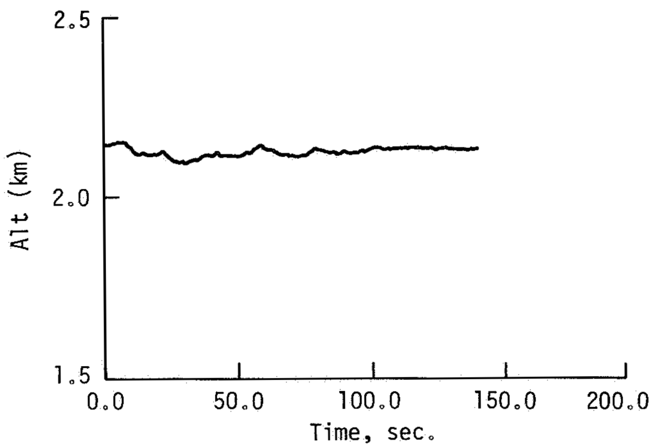

Figure 9. Altitude Trace for Run 14.

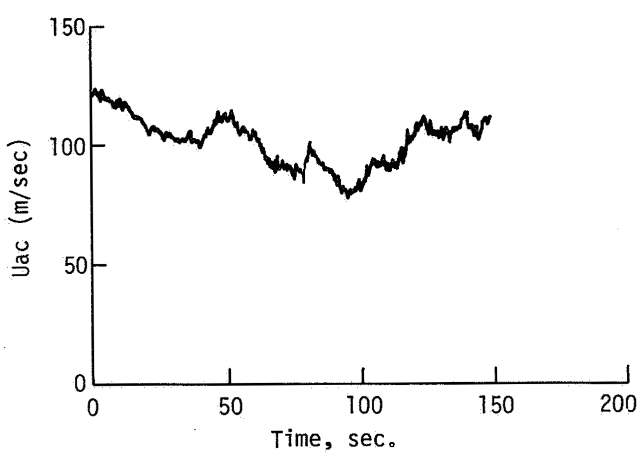

Figure 10. True Airspeed for Run 10.

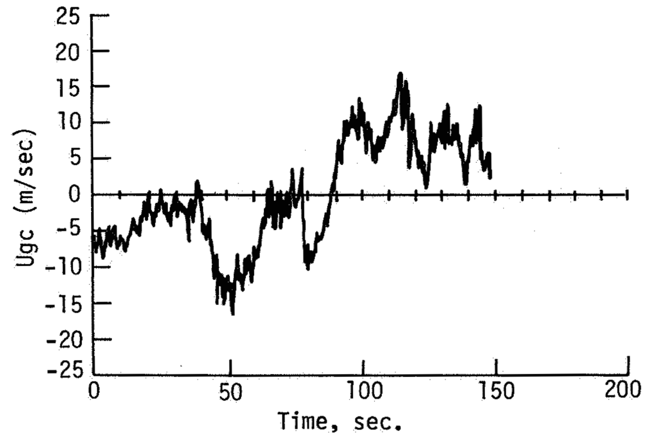

Figure 11. Ugc for Run 10.

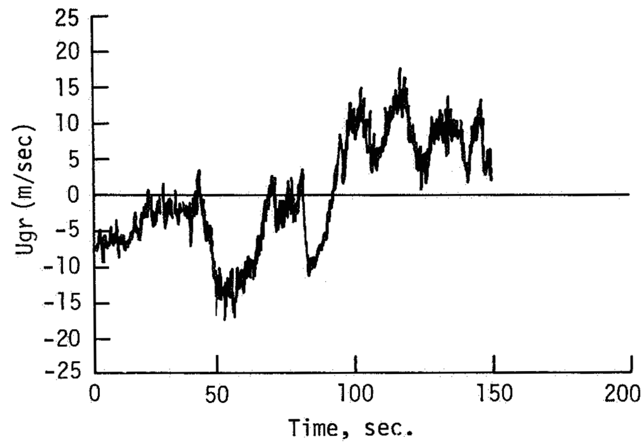

Figure 12. Ugr for Run 10.

to whether or not significant velocity changes occur across the wingspan. Figures 13 - 15 indicate that significant gradients do occur.

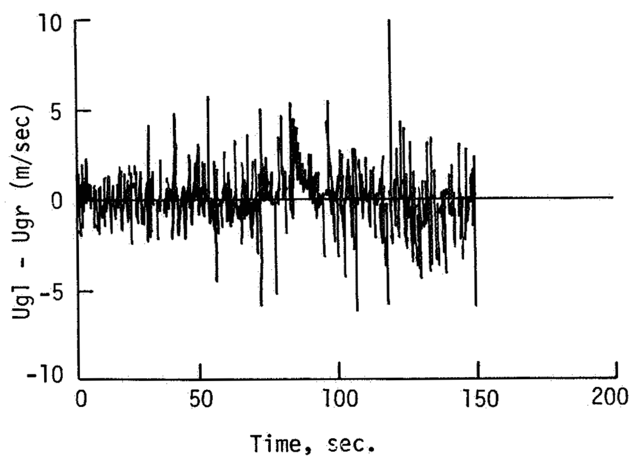

Figure 13. Ugl - Ugr for Run 10.

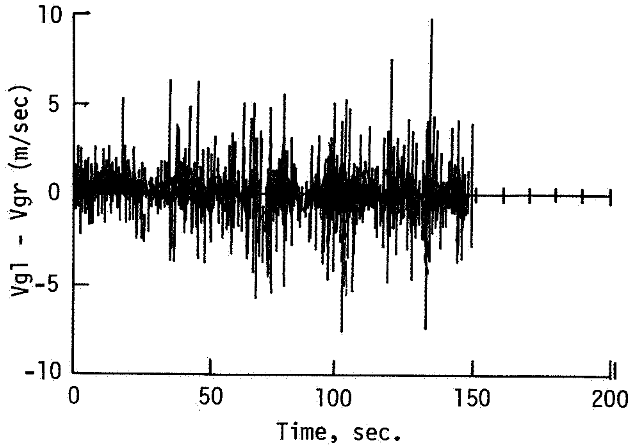

Figure 14. Vgl - Vgr for Run 10.

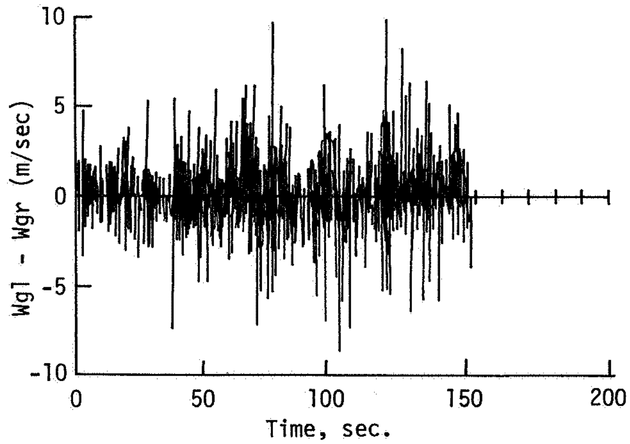

Figure 15. Wgl - Wgr for Run 10.

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