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COVER: (Top) Color-enhanced NOAA-9 image of the storm complex responsible for the Edmonton tornado of July 31, 1987. The lower storm was centered over Edmonton and the tornado was on the ground as this image was received. (Image courtesy of J. Bullas and R. Goodson, Atmospheric Environment Service, Edmonton, Alberta, Canada.)

(Bottom) The Edmonton tornado, July 31, 1987. This photograph was taken at about the same time as the NOAA image. (Photograph courtesy of Steve Simon, Edmonton Journal, Edmonton, Alberta, Canada.)

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"PROVIDING OPERATIONAL GUIDANCE FOR THE DEVELOPMENT OF SEA BREEZE THUNDERSTORMS AT THE KENNEDY SPACE CENTER: AN EXPERIMENT USING A MESOSCALE NUMERICAL MODEL"

by

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1. INTRODUCTION

While the term "severe thunderstorm" in a public forecast issued by the National Weather Service refers to a convective storm with wind gusts over 58 mph and hail 0.75" or larger, lesser storms can still inflict severe disruptions on the US Space Program. As highlighted by Boyd and Myers (1986), highly restrictive weather conditions attend a launching or landing of the Space Shuttle (no hydrometeors along the flight path, no runway crosswinds above 8 m s^{-1}, no electrical activity in the vicinity, etc.). Thus thunderstorms pose a major constraint on Shuttle (as well as other) operations at NASA's Kennedy Space Center (KSC). Up to 40% of central Florida's precipitation results from sea breeze convection (SBC) storms during synoptically quiescent periods. Extensive efforts are underway to improve observations, nowcasting, and short-range predictions at KSC. Boyd and Myers (1986) highlighted the technology that has been deployed (satellite, radar, wind mesonets, electric field mills, lightning detection networks, McIDAS-based interactive graphics systems). Watson et al. (1987) reported on promising short-range (60 - 120 minute) SBC storm forecasting techniques using low-level convergence signals from the KSC WINDS mesonet. However, in most cases additional forecast guidance is needed. Beyond the scope of nowcasting and short-range methodologies, for planning purposes of periods of up to 12 hours, additional guidance is necessary. A senior forecaster with years of experience can provide valuable subjective predictions. Such rare individuals, however, are either not always on duty or stationed on a semi-permanent basis. Artificial Intelligence (AI)/Expert Systems also appear promising in augmenting the experience level at a forecasting site such as KSC. Yet clearly, a scheme providing objective sea breeze thunderstorm forecasting guidance for the next 12 hours would be of benefit to those tasked with preparing terminal forecasts at 1600 Z. This paper is an interim report on an ongoing three year project, funded by NASA KSC, under the Small Business Innovation Research (SBIR) Program, evaluating the effectiveness of a mesoscale numerical model (MNM) in providing improved local forecast guidance, specifically with regards to SBC storms at KSC and over central Florida.

TABLE 1

P2DM/P3DM MODELING SYSTEM

CHARACTERISTICS AND CONFIGURATION:

Progenitor: NOAA Florida Sea Breeze Model (Pielke, 1974)
Primitive Equations, Hydrostatic
Noncondensing Atmosphere
Boundary Layer Fluxes (Businger, 1973)
Surface Heat and Moisture Balance (McCumber, 1980)
Soil Modeling (McCumber, 1980)
Time Step: 60 Seconds
Domain: 60 (E-W) x 50 (N-S)
Grid Size: 7.5 km (variable 2.5 km to 20 +km)
Vertical levels: 18 (6 to 25)

INITIALIZING DATA:
Land/Water Boundaries
Land Usage: Roughness: Albedo
Geostrophic Wind
Radiosonde(s) (T, TD, DD, VV) [1 to 6]
Ocean Surface Temperatures (4 zones)
Soil Wetness (5 zones)
Day of the Year
Cirrus Cloud Cover

MODEL OUTPUTS:
Wind: u, v, w, w Max, Speed, Direction
Thermal: Temperature, Potential Temperature
Moisture: Specific Humidity, Relative Humidity
Surface Pressure, Air Density, Index of Refraction (N)
Speed of Sound, Pasquill-Gifford Stability
KLIW Index, K Index, Lifted Index
Precipitable Water, Lapse Rates, Wind Shear

FORMATS:
XY Plan Sections
XZ Vertical Sections
XT, ZT Time Sections
"Synthetic" Tower Data

OUTPUT INTERFACES TO:
Lagrangian Particle Model (LPM)
Diagnostic Cloud Model (DCM)
CSU Cumulus Parameterization

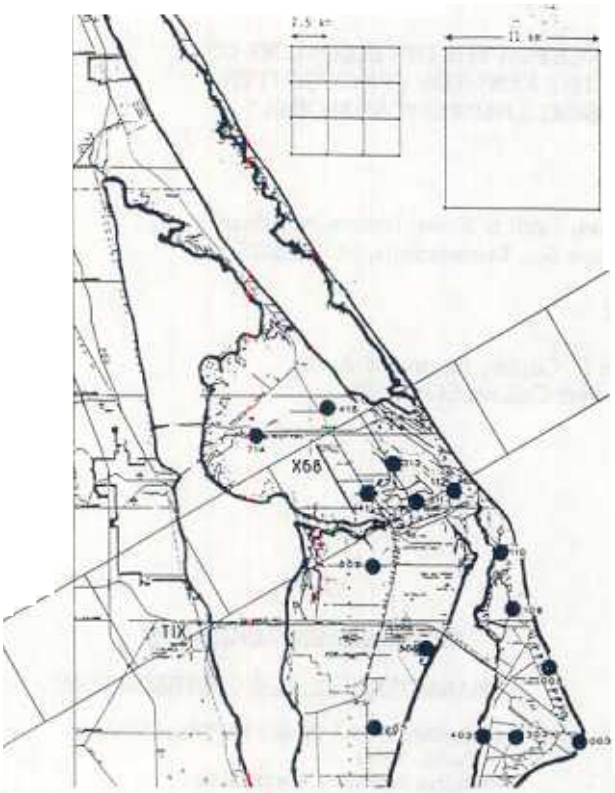

Fig. 1. A portion of the 7.5 km P2DM grid in the vicinity of the Shuttle Landing Strip (X68), which is model cell 45 (out of 60). Black dots represent some of the observation points within the KSC WINDS mesonet. The model has been run with grid sizes ranging from 2.5 km to 11 km (see insets).

STATION ID: 74794
DAY OF REPORT: 1
TIME OF REPORT: 12 Z

PRESSURE (MB)	MSL ALTITUDE (FEET)	TEMP (C)	DEW POINT (C)	WIND DIR/SPEED (DEG/KTS)
1018		23.4	22.1	220/002
1000	500	24.2	22.8	255/007
990		24.8	23.3	
940		21.2	19.2	
915		21.0	16.6	
850	5200	16.8	10.8	250/011
797		14.2	5.2	
700	10500	6.6	-.4	245/010
680		5.2	-.8	
672		4.6	1.8	
608		-.1	-4.0	
603		.2	-7.8	
590.		-.5	-13.5	
556		-3.7	-10.7	
549		-4.7	-6.2	
540		-5.5	-9.0	
539		-5.7	-12.7	
526		-5.9	-13.9	
507		-8.9	-10.8	
500	19300	-8.9	-15.9	035/006
483		-10.5	-16.5	
435		-13.3	-30.3	
400	24900	-18.1	-29.1	030/014
383		-19.9	-32.9	
377		-19.7	-32.7	
300	31800	-34.1	-46.1	065/024
292		-35.9	-46.9	
270		-38.5	-48.5	
250	35900	-42.7		060/031
200	40700	-54.5		065/031

Fig. 2. KSC sounding, 1200 Z, 1 July 1986, used in the case study presented here. Up to six regional soundings can be used to initialize the model. This format, as received from a commercial interactive data base, can be used directly to initialize the model run.

Fig. 3. Two samples of the numerous tabular outputs generated by the P2DM/DCM. The top panel shows a variety of parameters used for a "quick look" at the model results. The lower panel is an example of a "synthetic meteorological tower" designed to emulate the 150 m tower near X68. These can be "installed" at multiple locations in the model domain.

TABULAR HOURLY DATA

		X68 VALUES						GRIDS 41-47						SIRIP VALUES							
			WMAX	K	LI	KLIW	DIV *10E6 1/S	KLIW SUM	DIV MAX	WMAX MAX CM/S	K MAX	LI MAX	KLIW MAX	DIV MAX	Q AT 750M MAX	Q AT 750M AVG	Q AT 1250M MAX	Q AT 1250M AVG	Q AT 2250M MAX	Q AT 2250M AVG
		0.	1.	30.	-2.	1.	17.	6.	-73.	1.	30.	-3	1.	-73	14.7	14.6	11.4	11.3	6.8	6.8
		0.	1.	30.	-2.	1.	29.	7.	-27.	1.	30.	-3	1.	-27	14.8	14.6	11.4	11.3	6.8	6.8
		0.	1.	30.	-2.	1.	14.	7.	4.	1.	30.	-3	2.	-50	14.9	14.6	11.4	11.3	6.8	6.8
13Z	6.	0.	0.	30.	-2.	1.	8.	7.	-1.	1.	30.	-3	2.	-43	15.5	14.9	11.4	11.3	6.8	6.8
14Z	5.	0.	1.	30.	-2.	1.	19.	7.	-15.	1.	30.	-3	2.	-41	16.8	15.4	11.5	11.3	6.8	6.8
15Z	5.	0.	0.	30.	-3.	1.	-8.	10.	-22.	1.	30.	-4	3.	-35	17.7	15.9	11.8	11.3	6.8	6.8
16Z	5.	0.	1.	30.	-3.	2.	-21.	14.	-60.	2.	31.	-5	3.	-60	18.0	16.1	12.5	11.4	6.8	6.8
17Z	4.	0.	4.	31.	-4.	6.	-68.	32.	-101.	4.	32.	-6	6.	-101	17.8	16.0	15.0	12.2	6.9	6.8
18Z	4.	0.	9.	32.	-5.	7.	-179.	40.	-192.	9.	33.	-6	7.	-192	17.8	15.9	16.7	13.1	6.9	6.8
19Z	3.	0.	13.	34.	-5.	9.	-291.	47.	-291.	13.	34.	-7	9.	-291	17.8	15.9	17.5	13.5	7.0	6.8
20Z	2.	0.	14.	35.	-6.	9.	-340.	51.	-340.	14.	35.	-8	9.	-340	17.9	16.0	18.1	13.8	7.2	6.8
21Z	1.	0.	15.	35.	-6.	9.	-371.	51.	-371.	15.	36.	-8	9.	-371	18.2	16.1	18.2	13.9	7.4	6.8
22Z	1.	0.	16.	36.	-6.	10.	-409.	50.	-409.	16.	36.	-8	10.	-409	18.1	16.0	18.0	13.9	8.6	6.9
23Z	.0.	26.	14.	36.	-6.	9.	-399.	51.	-399.	15.	36.	-8	10.	-399	18.1	15.9	17.8	13.8	9.4	7.1
0Z	-4.	97.	11.	36.	-7.	9.	-321.	55.	-349.	17.	37.	-8	10.	-349	18.0	15.7	17.6	13.6	10.4	7.1

SYNTHETIC TOWER DATA FOR X68

	10 M					60 M					150 M				
TIME	PRES	T(C)	TD(C)	WS(KT)	WD	T(C)	TD(C)	WS(KT)	WD	L(C/100M)	T(C)	TD(C)	WS(KT)	WD	L(C/100M
10Z	1017.1	24.6	23.1	7.	222.	24.7	22.8	8.	225.	0.2	23.9	22.6	8.	228.	-0.5
11Z	1017.1	25.0	23.3	6.	222.	24.7	22.9	8.	226.	-0.6	23.8	22.5	8.	229.	-0.8
12Z	1017.0	26.0	22.9	6.	231.	25.3	22.6	7.	233.	-1.3	24.4	22.3	8.	235.	-1.1
13Z	1016.7	27.1	22.5	6.	237.	26.3	22.2	7.	238.	-1.7	25.3	22.0	8.	238.	-1.3
14Z	1016.5	28.2	22.5	5.	236.	27.2	22.1	6.	237.	-2.0	26.2	21.8	7.	238.	-1.4
15Z	1016.2	29.1	22.2	5.	237.	28.0	21.8	6.	237	-2.1	27.0	21.6	7.	237.	-1.5
16Z	1015.8	29.9	22.3	5.	234.	28.8	21.9	6.	234	-2.2	27.8	21.7	6.	235	-1.5
17Z	1015.5	30.7	22.5	4.	227.	29.6	22.0	5.	229	-2.2	28.6	21.8	5.	229	-1.5
18Z	1015.1	31.5	22.2	4.	221.	30.5	21.8	5.	223	-2.2	29.4	21.5	5.	224	-1.5
19Z	1014.8	31.9	22.2	3.	208.	31.0	21.7	4.	213	-1.9	30.0	21.4	4.	218	-1.4
20Z	1014.6	32.0	22.6	3.	186.	31.3	22.0	3.	198	-1.6	30.3	21.7	4.	202	-1.2
21Z	1014.4	32.1	22.9	3.	160.	31.4	22.4	4.	173	-1.3	30.6	22.1	4.	188	-1.1
22Z	1014.3	31.9	22.9	3.	170.	31.5	22.3	4.	174	-0.9	30.7	22.0	5.	190	-0.9
23Z	1014.2	31.0	23.6	3.	144.	31.1	22.8	5.	158	0.2	30.6	22.4	5.	182	-0.3
0Z	1014.2	28.4	24.9	6.	110.	30.1	23.6	8.	131	3.4	30.2	22.8	6.	166	1.3

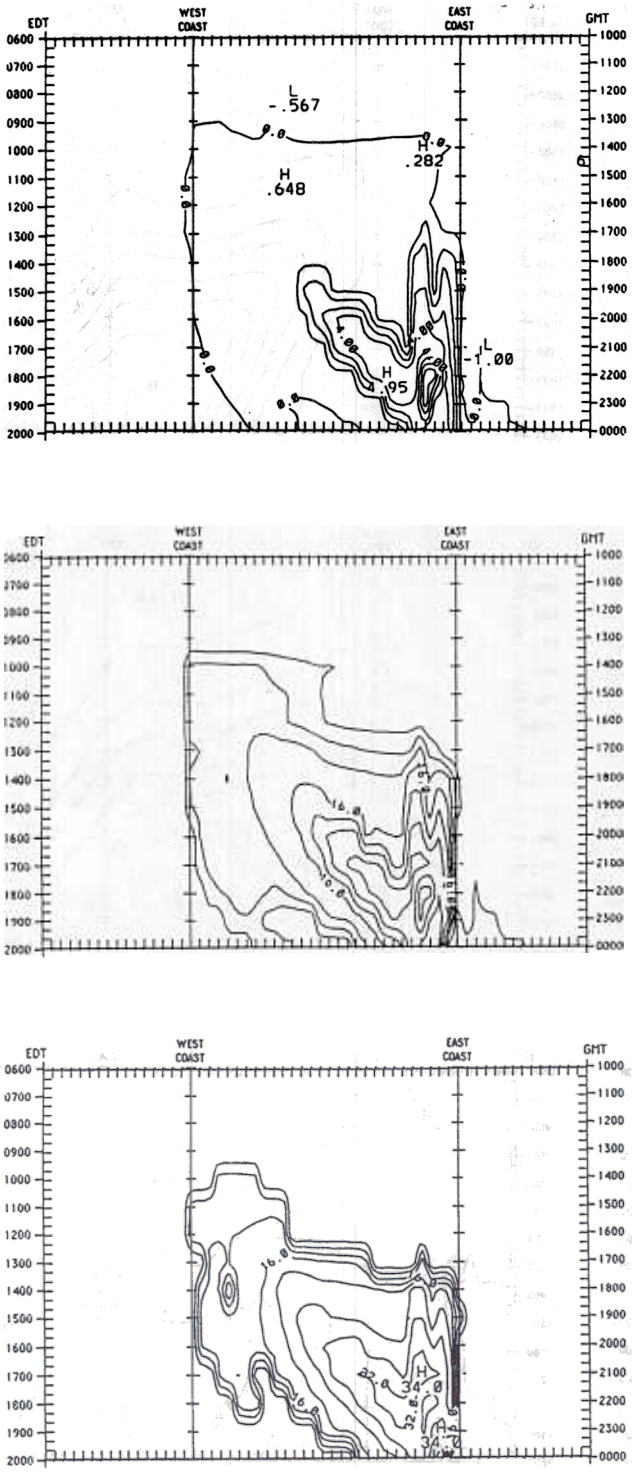

Fig. 6. DCM generated output for 1 July 1986 in XT format. (TOP) DCM stability, 1.0 isopleths, probability and intensity of convection increases with increasing positive values. (MIDDLE) In-cloud updrafts, 4 m s^{-1} intervals, with entrainment and water loading accounted for, of convective elements scaled to the depth of the surface mixed layer. (BOTTOM) Maximum surface wind gusts (knots) expected with thunderstorm downdrafts, 4 knot intervals.

2. MESOSCALE MODEL DESCRIPTION

The MNM selected for this experiment has evolved from the original Florida sea breeze model developed by Pielke (1974). Currently called the Prognostic Three-Dimensional Mesoscale (P3DM) Model (and the P2DM, its two-dimensional counterpart), it is thoroughly described in Pielke (1984). During Phase I of this project (Lyons et al., 1987), the P3DM was run (with a 50 x 60 domain and an 11 km grid, 18 levels) for all of peninsular Florida for three case study days with relatively similar synoptic conditions. It was shown that although a sea breeze was present on each day, the character of the resultant SBC storms was substantially different, ranging from virtually nill to locally severe and widespread. The P3DM confirmed the results of earlier studies that showed the strength of the SB and its ability to generate local (meso-beta scale) pockets of moisture convergence was a complex function of the geostrophic flow and the vertical profiles of temperature, moisture, and wind. Careful analysis of model-computed stability fields (using standard measures such as the K and Lifted Indices) and SB vertical motions showed that the potential for SB triggered convection varied both temporally and spatially in highly complex patterns during the course of the diurnal cycle. In order to better evaluate the impact of both thermodynamic and dynamic factors in SBC storm generation, a new hybrid index was proposed. By combining the perturbations of the K and Lifted Indices and the maximum vertical motion (w) at each grid cell within the model, the KLIW Index was computed (KLIW ranges from 0 = no convection to 12 = widespread intense storms). Comparison of the KLIW fields to actual SBC storm patterns suggested a useful prognostic tool was evolving. During Phase II of the project, 30 additional SB days during 1986 were studied. Initial evaluations indicated the P2DM model indeed could provide to the forecaster useful guidance as to the timing, location, and (at least) initial characteristics of SBC storms over central Florida (Lyons et al.,1987).

The final phase of the project, which involved providing actual model output to forecasters on a quasi-daily basis, was conducted during the Summer of 1987. First, deficiences noted in the model were corrected. In particular, regional wind fields (using up to 6 radiosondes) could be used for model initialization. Spatial variability of sea surface temperature (4 zones) and estimated soil moisture (5 zones) could be more easily accounted for. Cirrus cloud cover was approximated by allowing an ellipsoidal area of arbitrary size, transmissivity, speed and direction to advect through the model domain. The model was installed on the CYBER 205 at the Minnesota Supercomputer Institute. Original plans called for using the P3DM on an even faster ETA 10 computer. Federal funding cutbacks prevented delivery of the ETA 10 in time for the 1987 season. Thus the P2DM, using a 7.5 km grid, with a nominal 3 minute CPU runtime (versus 150 minutes for the P3DM) was employed (see Fig. 1 for the grid in the KSC area). The P2DM domain was 450 km wide, and oriented normal to the coastline at KSC (30 degrees

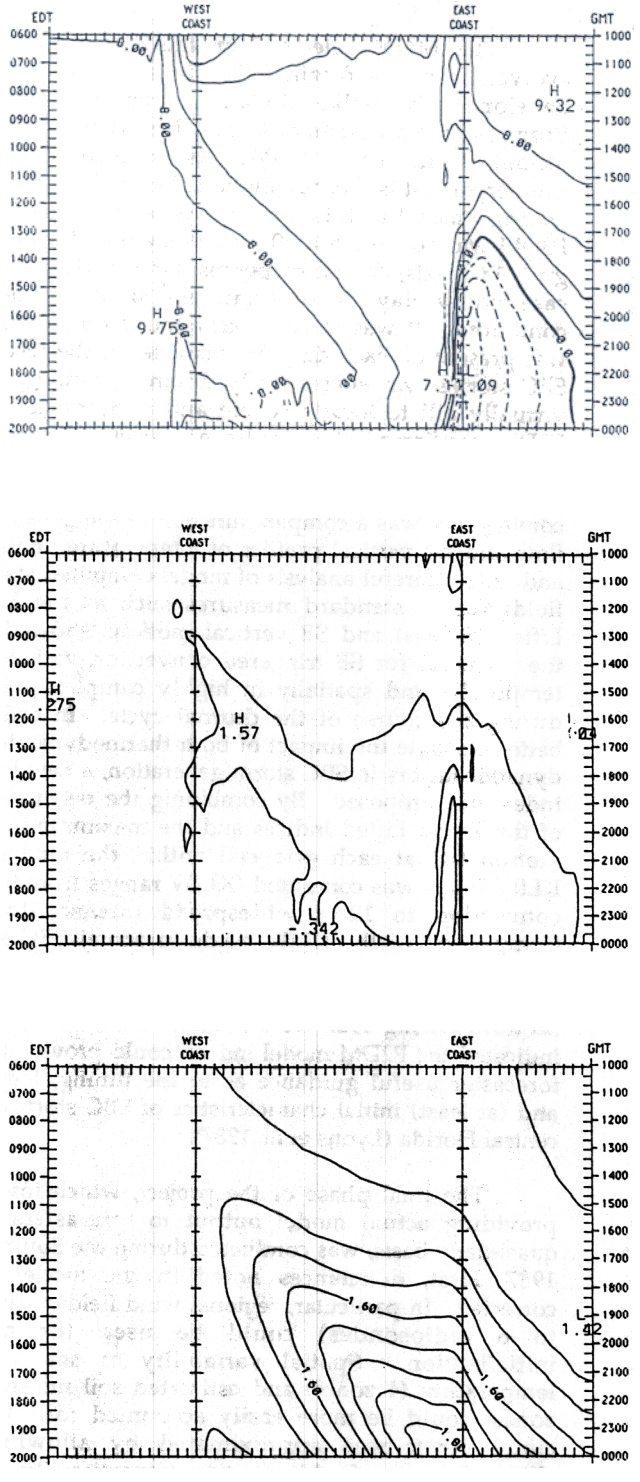

Fig. 4. P2DM output, 1 July 1986, in the XT format. Time increases from top to bottom, and the entire 60 grid cells (450 km) of the P2DM, which are oriented along a roughly KSC-Tampa line, are shown (along with the east and west coastlines). (TOP) U component (knots) at 2 kt intervals (onshore, along EC, is doted). (MIDDLE) Maximum grid cell upward vertical motions , at 5 cm s^{-1} intervals. (BOTTOM) Precipitable water, in inches, from the surface to 500 mb (0.05 inch intervals).

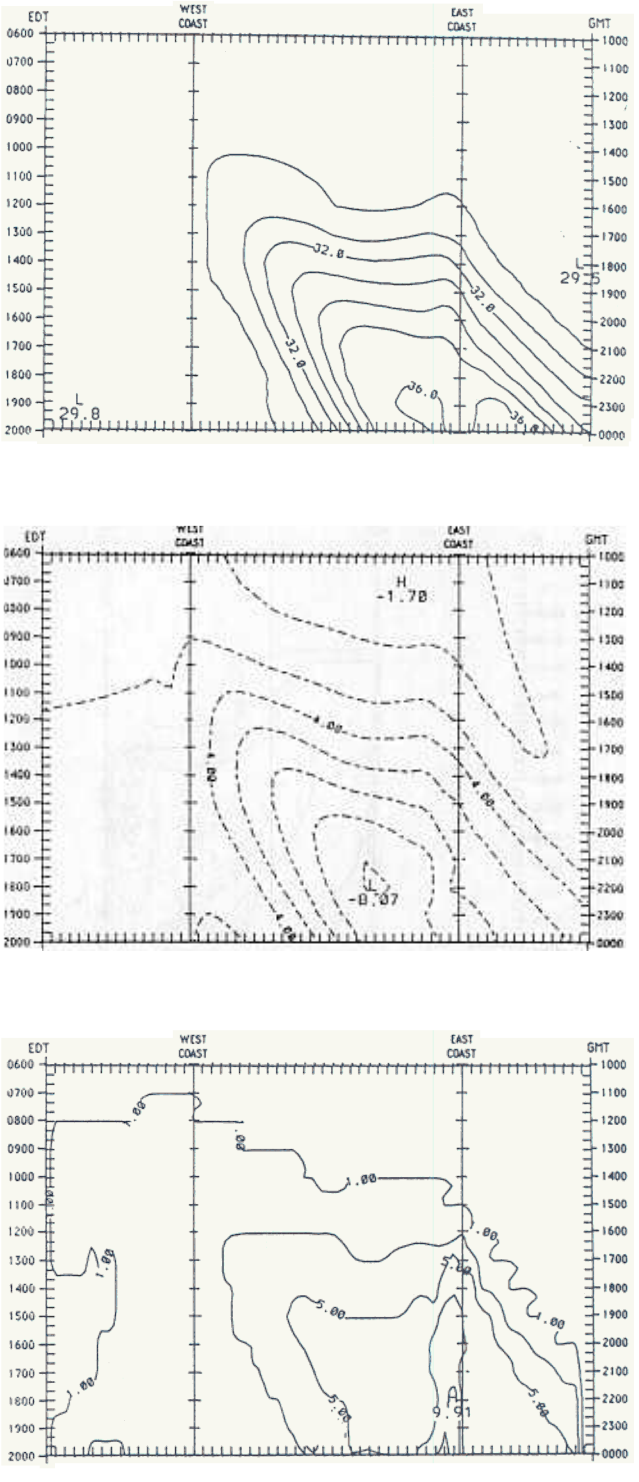

Fig. 5. P2DM-generated stability indices, in the XT format, for 1 July 1986. (TOP) K index, 1 unit isopleths. (MIDDLE) Lifted Index, surface to 1500 m, 1 degree isopleths. (BOTTOM) The KLIW index, 2 unit isopleth intervals. Values range from 0 to 12. At KLIW = 1, widely scattered rainshowers possible. For KLIW values above 5, thunderstorms become increasingly numerous and vigorous. KLIW ≥ 9, thunderstorms are widespread and intense.

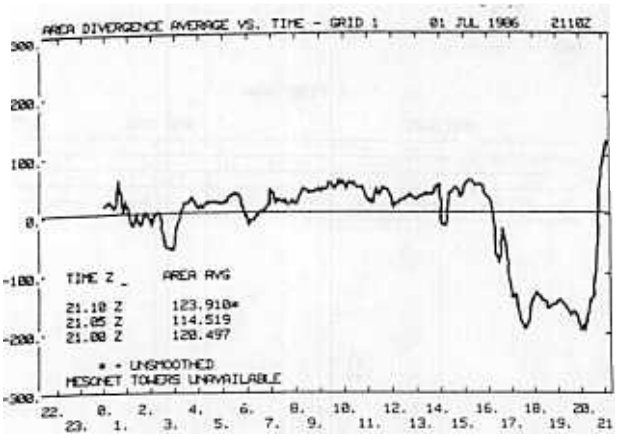

Fig. 7. Areal average divergence from KSC WINDS mesonetwork, 1 July 1986, showing the onset of the "convergence event" beginning about 1630 Z, and ending with the thunderstorm-induced divergence about 2030 Z (Units, $\times 10^{-6}$ s^{-1}).

TABLE 2. HOURLY OBSERVATIONS AT THE KSC SHUTTLE LANDING STRIP (X68)

TIME (Z)	SKY COVER	VIS (NM)	WX	T °C	TD °C	WIND °/KTS	REMARKS
1500	SCT	10		30.6	23.9	21/05	
1600	SCT	10		31.7	22.3	20/05	
1700	BKN	10		32.8	21.7	21/06	CB NW, LTL MOVMNT, TCU S-W-NW
1800	BKN	10	RW-	31.7	21.1	19/03	CB NW, MOVG SE
1900	BKN	10		30.0	25.0	09/09	TCU S-W-NW
2000	BKN	7	T	27.8	25.0	08/06	T W, MOVG E, OCNL LTGCG W
2100	OVC	0.5	TRW+	22.2	22.2	34/11	T OVHD-E, MOVG E, OCNL LTGICCCCG
2200	OVC	7	TRW-	22.8	21.1	18/12	T SE-S, MOVG E
2300	OVC	7	TRW-	22.8	21.7	17/08	T SE-SW, STNRY
0000	OVC	7		22.8	21.1	17/06	RAIN 2.41"

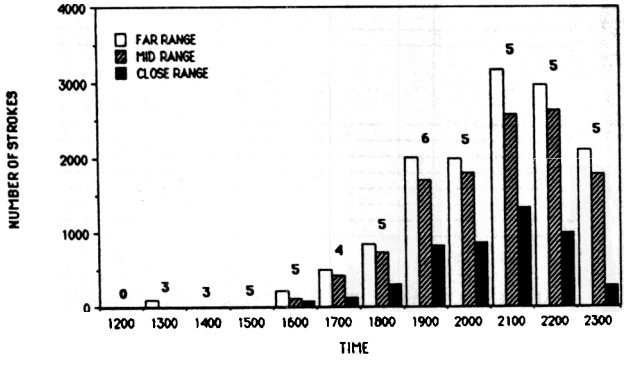

Fig. 8. Summary of total CG strokes from the Florida LPATS network for 1200 - 2300 Z, 1 July 1986 (total 13,784). Hourly counts for the far range (all of Florida except the panhandle), the mid range (a radius of about 220 km of KSC) and the close range (radius of 110 km from KSC).. Numbers indicate the maximum DVIP level reported by the Daytona Beach WSR-57 radar in its hourly observation.

from true north). Input routines were simplified to allow the model initialization to be accomplished within several minutes. A typical sounding as received from the Kavouras, Inc. interactive data base (Fig. 1) could be ingested directly. Output routines were re-written to produce a wide variety of displays which would be easily comprehended by an operational forecaster after minimal familiarization (Fig.3). The revised P3DM/P2DM characteristics are summarized in Table 1 (a more complete description of the modeling system will be the subject of a later paper).

Another significant upgrade for the 1987 experiment involved the development of the Diagnostic Cloud Model (DCM). The KLIW Index, while promising, is entirely empirical. A need was perceived for a more quantitative measure of the response of the atmosphere to SB-induced meso-beta scale moisture convergence and vertical motion. The DCM (also the subject of a follow-on paper) is essentially a 1-D cumulus model having some resemblance to the Fritsch-Chappell parameterization scheme. It is executed at each model grid point on an hourly basis, employing a "best-lifted level" approach from 150 m to 1750 m. It accounts for entrainment/detrainment and water loading. The initiating convective element is scaled by the local depth of the model generated planetary boundary layer. Tests reveal the DCM is strongly responsive to local moisture convergence features such as the sea breeze. The DCM output includes: the DCM stability (related to the probability and intensity of convective development, increasing with positive values, with 4+ representing vigorous potential storms), average cloud top heights, maximum radar DVIP level, maximum in-cloud updraft and downdraft speeds, and estimated surface wind gusts associated with storm outflows. Analysis of the model output was accomplished, in part, using the NCAR graphics package.

3. PRODUCING OPERATIONAL FORECAST GUIDANCE

During the period 8 June to 28 August 1987, the upgraded P2DM/DCM code was executed on all weekdays for which sea breeze activity was expected over central Florida. This totaled 54 days (in addition, 10 days from 1986 have been re-run). During "go-days", the R*SCAN Nowcast center archived substantial amounts of data for model evaluation purposes: all regional surface and upper air observations, radar SD and severe weather reports, GOES tap imagery (UNIFAX II and NVG video facsimile), hourly RADAC images (4 ranges, at 35 minutes after the hour) from the Daytona Beach (DAB) WSR-57, and hourly downloads of lightning cloud-to-ground (CG) strokes from the Florida LPATS network (Lyons et al., 1986). The radar DVIP levels and CG stroke data are being digitized into 7.5 km^2 cells coincident with the model. On a typical day, a preliminary go/no go decision would be made by 1200 Z. Between 1400Z and 1500 Z, data, including the KSC radiosonde, would be assembled for a final go/no go

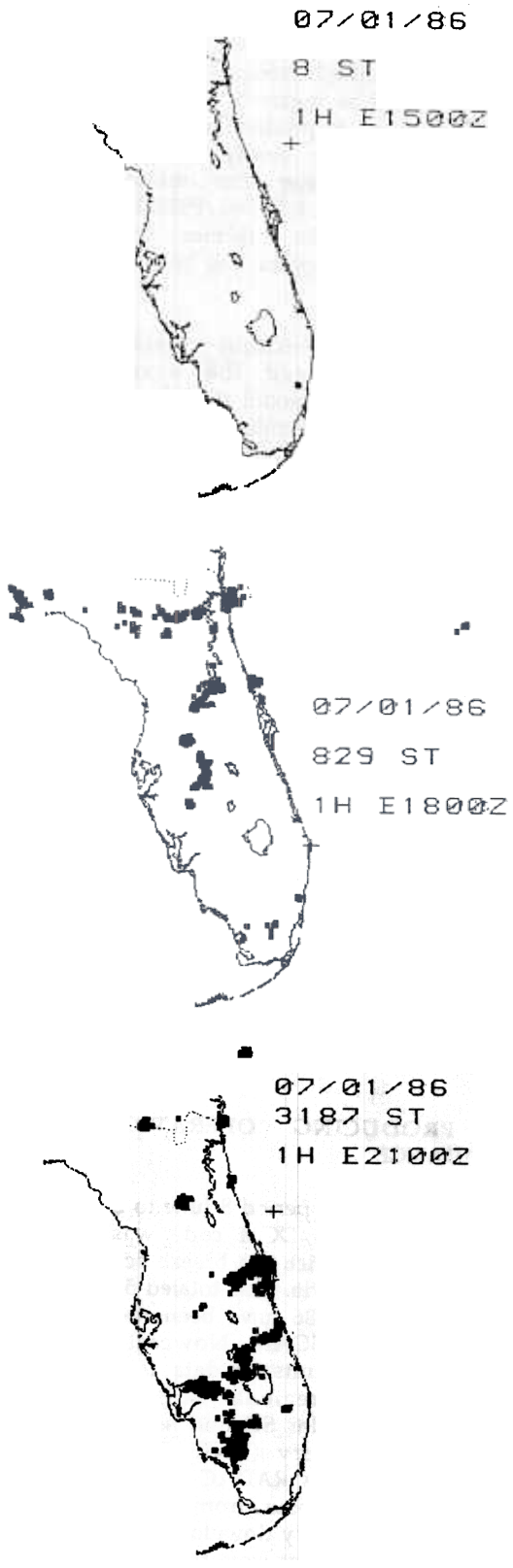

Fig. 9. Hourly plots of CG strokes from the Florida LPATS network for 1 July 1986 for hour ending 1500 Z (TOP), 1800 Z (MIDDLE) and 2100 Z (BOTTOM). At 1880 Z, note the band of electrical activity associated with the WCSB impulse that had already moved into central Florida.

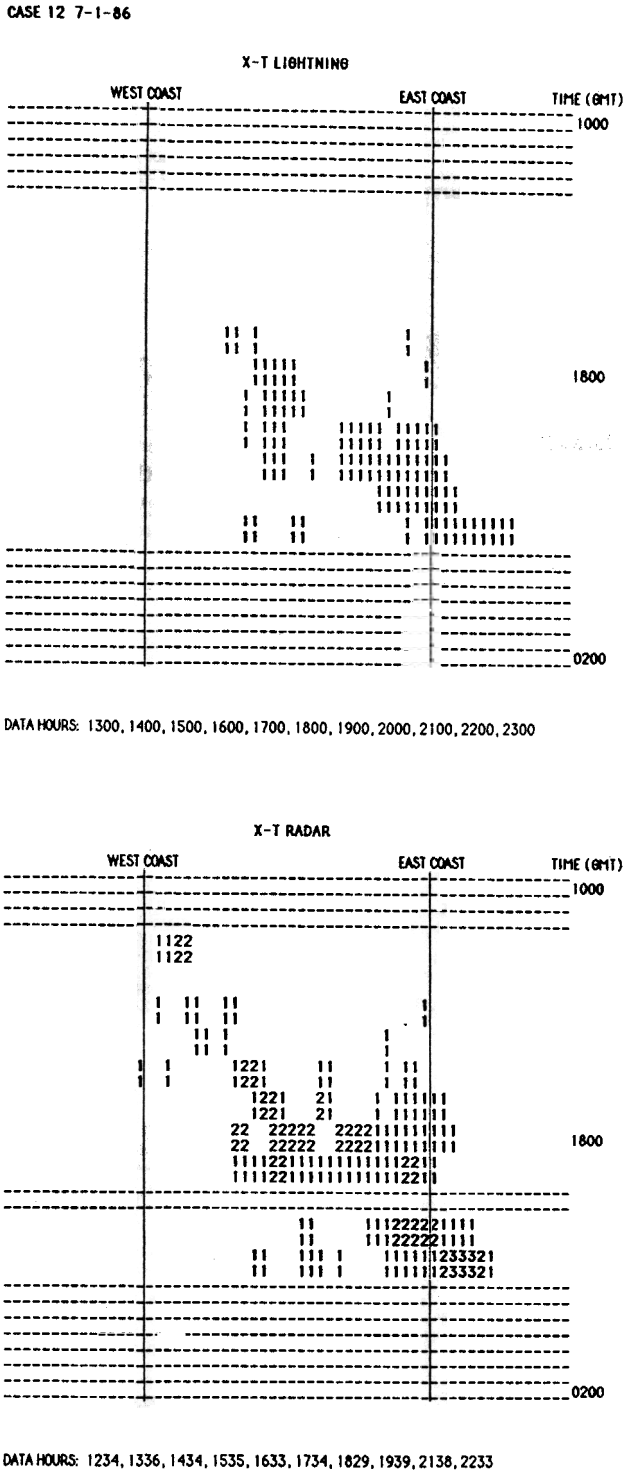

Fig. 10. Summaries of lightning CG events (TOP) and radar DVIP levels (BOTTOM) in XT format for 1 July 1986. In the CG plot, "1" indicates the occurrence of one or more CG events in a 7.5 x 75 km cell (the strip) during the previous hour. Radar data, taken at 35 minutes after the hour (nominally), were hand digitized onto the 7.5 km model grid. "1" refers to DVIP levels 1 or 2, "2" refers to DVIP levels 3 or 4, and "3" indicates DVIP levls 5 or 6 present.

decision (a subjective forecast as to SB development) followed, if go, by model initialization. Computational turnaround and graphics production (which included over 200 pages of laserprinter output) could take between 15 and 120 minutes depending upon CYBER 205 usage. Our stated goal was to have the P2DM/DCM run, evaluated, summarized (in a 200 word synopsis, plus about 10 selected graphics), and transmitted via facsimile to KSC (and several other locations) by about 1600 Z. This goal was approached on most days. During the subsequent nine month period, R*SCAN will perform extensive evaluations of the resulting forecasts; both of the model's performance (without any human interpretation) as well as its impact (by a series of blind tests) on the accuracy of the predictions of a human forecaster. In order to illustrate the process, we will use a case study day from 1986 for which radar and LPATS CG data have already been digitized.

4. A CASE STUDY: 1 JULY 1986

1 July 1986 dawned virtually cloudless over Florida. Rather typically, a ridge associated with the Bermuda summer anticyclone was positioned to the south of KSC, whose sounding (Fig. 2) showed deep and relatively moist southwesterly flow through 3000 m (surface geostrophic wind, 240 degrees, 4.6 m s^{-1}) with northeasterly flow aloft. Regional K Index values averaged about 30 units. We note, based on climatology, that there is about a 45% chance of a thunderstorm at X68 during the 1500 - 0300 Z period (Lyons and Fisher, 1988). A seasoned forecaster, armed with routine observations, would have little difficulty in anticipating an east coast sea breeze (ECSB). This pattern has also been identified by Watson et al. (1987) as frequently associated with SBC storms and lightning events in the KSC vicinity. The question now focuses to one of timing of the events and the details of their development. A more junior forecaster would most likely prefer confirmation of any similar prognosis derived from conventional procedures.

Figure 3 shows typical tabular output derived from the P2DM/DCM. Included are: (1) an emulation of the readings on the 150 m tower located near the Shuttle landing strip (X68) as well as hourly summaries of predictions at X68 itself, (2) conditions in a region about 50 km wide centered on X68, and (3) the strip running through Florida from roughly KSC to Tampa. A number of features are noted. The ECSB onset at X68 is considerably delayed, perhaps as late as 2230 Z, although light winds run parallel to the shoreline most of the afternoon. Values of KLIW at X68 (and their sum from grid cells 41 to 47) both reach levels associated with widespread SBC storms. Surface convergence values near X68 reach very high values after 1700 Z. Maximum ECSB vertical motions approach 20 cm s^{-1}, local K and Lifted Indices destabilize from 30 to 36 and -2 to -7 respectively, and specific humidity values at 1250 m nearly double during the afternoon, indicating moistening of the upper PBL by the forced convection associated with the ECSB front. Thus, the first level of model output strongly suggests a late onset to the ECSB (typically the wind shifts at X68 around 1600 - 1700 Z) and a high probability of SBC storms after 2000 Z (but with scattered weaker rain showers in the area for several hours before). Figure 4 is a sample of the XT (space - time) display of the u wind component, the maximum vertical motion (w), and the surface to 500 mb precipitable water predicted by the P2DM. It is evident that a strong ECSB does develop by 1745 Z , but is prevented from moving more than one grid cell inland until after 2200 Z. Indeed the first stirrings of a sea breeze in the easternmost sites of the KSC WINDS mesonet were at 1700 Z (about three hours later than average). The ECSB updrafts remain almost stationary over the first two grid cells inland from the coast (15 km) during the afternoon. Note also the west coast sea breeze (WCSB) "impulse" that moves steadily eastward, beginning as early as 1300 Z. Experience has shown this feature to be extremely important, in spite of vertical motions which normally do not exceed 5 cm s^{-1}. A significant moistening of the lower atmosphere, especially over eastern Florida, as reflected by increases in precipitable water from about 1.45 to over 1.80 inches, are the result of the impact of the SB moisture convergence on a regional scale. Figure 5 examines stability indices derivable directly from the P2DM. The K Index becomes most unstable along the east coast (and for a distance offshore) by 2300 Z. A somewhat similar pattern is found in the Lifted Index, although the area of greatest destabilization shifts inland, reflecting PBL heating. The hybrid KLIW index shows a similar pattern. Again note that while the ECSB appears dominant, and that late afternoon thunderstorms near KSC are strongly suggested, a clear impulse, beginning rather early in the day, can be seen propagating eastward across the peninsula. This in fact has been found to be a common regime. Figure 6 shows several DCM generated outputs. The DCM stability parameter yields a similar pattern, with values over eastern Florida exceeding +5.0 units after 2000 Z. Peak updrafts reach at least 32 m s^{-1}. Maximum surface wind gusts of 34 knots are predicted.

A review of observed data shows a reasonably close correspondence between the P2DM and actuality. Figure 7 displays the WINDS network average divergence computations that are continuously monitored at the Cape Canaveral Forecast Facility (CCFF). According to Watson et al. (1987) this represents a classic "convergence event" in which strong low level convergence beginning around 1630 Z presages lightning CG events beginning as early as within 48 minutes (although only for 68 out of 112 occasions). Table 2 shows the hourly observations at X68. The ECSB may have reached inland as far as X68 by 1900 Z (although it never was indicated at Titusville (TIX) two grid cells further west).

Thunder began at X68 at 1955Z. Heavy thunderstorms continued in the area for three hours, with almost 2.5 inches of rainfall. Peak gusts noted within the WINDS network were 24 knots, with 28 knots reported by Daytona Beach. Figure 8 summarizes lightning CG activity and the maximum radar DVIP levels reported by DAB. As indicated by CG

counts, activity was moderately strong, with 13,784 strokes reported over peninsular Florida between 1200 Z and 2300 Z , with 4720 strokes within about 110 km of KSC. Peak electrical activity occurred between 2100 and 2200 Z. Figure 9 shows LPATS CG patterns for hourly intervals ending 1500, 1800, and 2100 Z. As frequently has been observed during the past two summers, during southwest flow, storms have first become active along the *west coast* sea breeze, and then rapidly propagating eastwards. ECSB activity remains relatively subdued (in spite of apparently stronger surface SB convergence zones and vertical motions) until the approach of the weaker WCSB "impulse". After 2000 Z, storms on the ECSB become much more active. Indeed cells continued moving eastward into the Atlantic during the late afternoon hours. The lightning and radar events in the "strip" (5 grid cells either side of the P2DM axis) are summarized in the same XT format used for the model output. Visual inspection shows a strong correlation between the model predictions and the observed. Data in this format will be used to develop objective evaluations of the P2DM/DCM model ouput for upwards of 60 case studies. Remotely sensed data, in particular, lightning ground-stroke observations, is proving to be an excellent resource for evaluating regional forecasts of convection.

5. SUMMARY AND CONCLUSIONS

This report summarizes work in progress on what is believed to be the first attempt in the US to transfer an MNM from the research laboratory into the field forecast office environment. It has been shown that with the power of the supercomputer, previous constraints on model application imposed by the clock are now fading. The real challange is in learning how to employ these complex systems in a real-world context. Improvements in model physics and parameterizations will be found to be no less difficult than those associated with learning how to interface the massive amount of output from such a system to the requirements of the operational forecaster. Initial experiments, using a blind tester, show that forecasts made with the assistance of the P2DM/DCM outperform purely subjective predictions of SBC storms at X68 (in terms of probability of detection and critical success index). The MNM can be used for a wide variety of purposes, including improved prediction of mesoscale dispersion for emergency response planning (Pielke et al., 1987; Lyons et al., 1988). Among the unexpected results of the 1986-87 program was the finding that, even with periods of westerly flow, convection associated with the WCSB impulse starts earlier and is often more vigorous than its ECSB counterpart. This phenomenon is now under active investigation.

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