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A "RED FLAG" DIAGNOSTIC FOR DETERMINING POTENTIAL AREAS OF LOW LEVEL WIND SHEAR USING PCGRIDDS

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1. Introduction

Although low level wind shear (LLWS) has been widely documented and accepted as a mesoscale feature, it has also been documented that many forms of non-convective shear have synoptic scale features that ultimately are the cause of a wind shear environment Badner (1978). Warm and cold frontal boundaries with sharp temperature gradients, and sustained surface winds greater than 30 knots are the dominant features. This paper presents two case studies where the NGM gridded model output and associated analysis tool PCGRIDDS performed remarkably in graphically depicting areas of synoptic, non-convective low level wind shear significant to aviation.

2. Discussion

In the wake of the airline crashes of the 1970's caused by low level wind shear, several meteorologists analyzed and dissected the problem on the synoptic and mesoscales of motion. Badner (1978) introduced a list of criteria for the severity of wind shear. The British Meteorological Office developed a checklist which deals with the vector difference between the surface wind and various multiples of the gradient level wind. Various rules of thumb for frontal boundaries using temperature gradients and vector differences across the boundaries were developed by Wachtmann (1978) and Jannson (1981). Chapter D-21 of the National Weather Service Operations Manual (WSOM) defines low level wind shear as a change of wind speed of 10 knots or greater per 100 feet in a 200 foot layer within 2000 feet of the surface. These forecasting techniques require a good deal of attention, detail, and calculations, and at times are probably discarded from the "weather watch" process due to a variety of operational constraints. With the increasing development of computer technology, many of these techniques can easily be computed and graphically displayed.

Based on that thinking, a PCGRIDDS (Meier 1993) macro was created utilizing the finer spatial resolution of the NMC gridded model output and diagnostic functions of PCGRIDDS (Figure 1). Since low level wind shear is the vector difference between the wind in two layers within 2000 feet of the earth's surface, this macro contours the magnitude of the vector difference between the winds in the lowest calculated sigma levels of the NGM model. The macro will plot the grid point winds and overlay contours of vector shear in the layer greater than 12 knots. Because the shear is calculated over a rather deep model layer, this minimum contour was chosen to coincide with the severe shear category in Badner's criteria which is 12 knots per 100 feet. Sigma level one is oriented at approximately 982-mb with respect to pressure surfaces, while the next available level (sigma level three) is around 896-mb. Although the depth of the layer between these two levels exceeds the National Weather Service (NWS) definition of LLWS, it was believed that the results would correlate to pilot reports of LLWS enough to be of use as an alert or "red flag" technique in an operational forecast setting.

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                 LLWS "FLAG" MACRO

AREA ## ## ##
WKNT BARB S982 F##
WKNT BARB S896&
MAGN LYDF WKNT CIN2 GT12 SLYR S982 S896&
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Figure 1. PCGRIDDS macro developed to determine LLWS.

3. Case Studies

Utilizing the gridded model output from 1200 UTC 10 May 1994, initial conditions, the PCGRIDDS macro (Figure 1) was integrated forward in time to 30 hours. The valid time of the forecast was 1800 UTC 11 May. Two maxima were noted over eastern Michigan and Ontario (Figure 2).

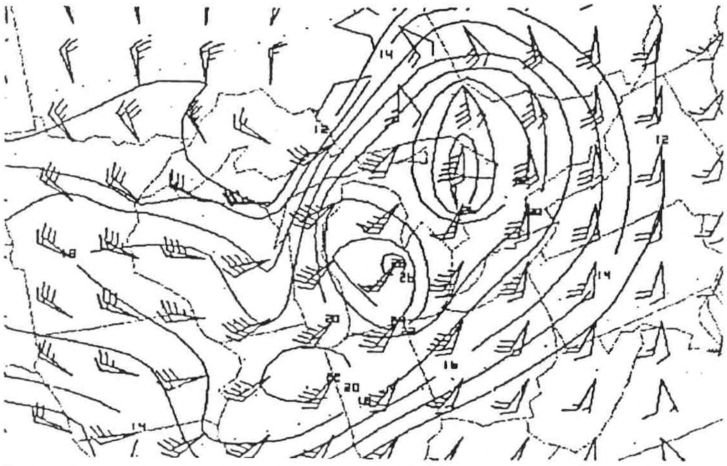

Figure 2. LLWS flag contours (kts) valid 1800 UTC 11 May 1994. NGM 30-hour forecast from 1200 UTC gridded model output May 10, 1994.

The next day, further use of the macro was conducted on the 1200 UTC 11 May run of the NGM gridded model output. The six-hour forecast valid at 1800 UTC nearly replicated the previous model contouring of LLWS (Figure 3a). Model synoptic surface features indicated a 996-mb sea level low pressure system over the Upper Peninsula of Michigan with its associated warm front stretching eastward through New York and cold front extending southwestward into South Dakota (Figure 3b).

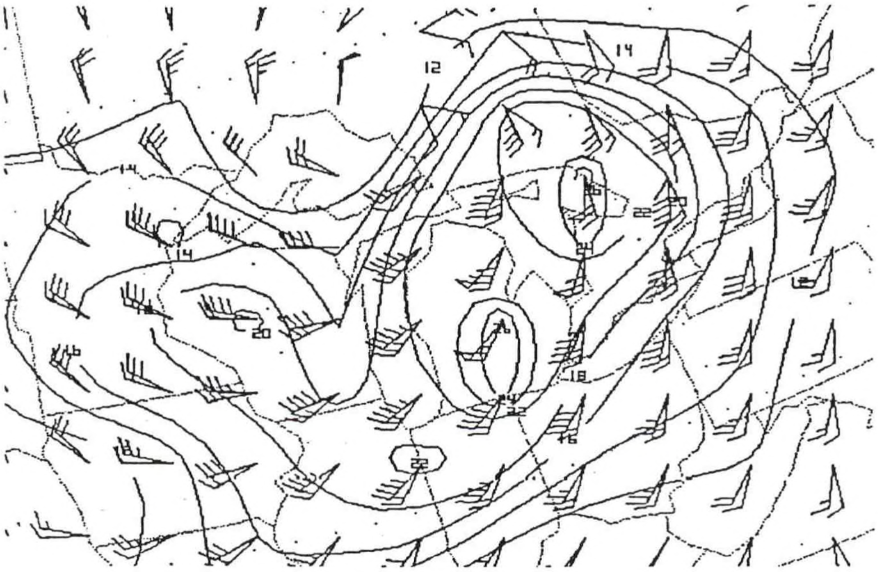

Figure 3a. LLWS flag contours (kts) valid 1800 UTC 11 May 1994. NGM 6-hour forecast from 1200 UTC gridded model output May 11, 1994.

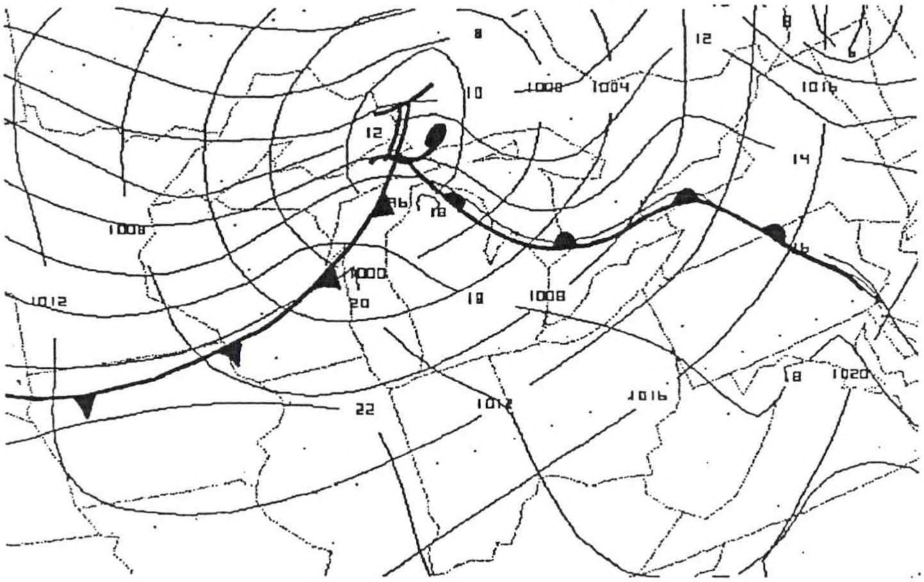

Figure 3b. Sea level pressure (mb), isotherms (°C) and subjectively analyzed frontal system forecast for 1800 UTC 11 May 1994. From NGM 6-hour gridded model output forecast 1200 UTC 11 May 1994.

The first pilot reports of LLWS occurred in Michigan and Wisconsin at 2000 UTC 11 May 1994. They indicated a +/- 10 to 15 knot shear on final approach (Figure 4). For the next several hours, pilot reports from within the contoured area continued to indicate wind shear and associated moderate to severe turbulence (Figures 5a and 5b). At the 0000 UTC valid time, the low was forecast to have occluded and moved northeast into Canada. The warm and cold fronts were progressing eastward and the suspect area for LLWS had shifted east into Quebec, Canada and New York (Figures 6a and 6b). After 0000 UTC, pilot reports began streaming in from New York, Pennsylvania and New Jersey (Figure 7), clearly verifying areas of LLWS being generated in the strong temperature gradient ahead of the warm front as predicted by the model output. By 0600 UTC the forecast continued to show a shear environment over the Northeast U.S., Pennsylvania and New Jersey (Figures 8a and 8b). It did indicate that these areas were now in a weaker LLWS gradient; and in fact, there was no longer confirmation of LLWS from pilot reports.

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UBUS1 KWBC 112000
 MI 112000
GRR UA /OV GRR/TM 1945/FL040/TP PA32/SK 075 SCT/TB NEG
LAN UUA /OV LAN/TM 1959/FLUKN/TP AT42/RM LLWS + -10KT FA28L

UBUS1 KWBC 112000
 WI 112000
GRB UUA /OV GRB/TM 2000/FLDURD/TP HS25/TB LLWS -10-15KTS/RM
FNL RY 3&
MWC UUA /OV MWC/TM 1956/FLDURD/TP C310/TB LLWS -10-15KTS/RM
NL RY 22
```

Figure 4. Initial pilot reports received from Michigan and Wisconsin, May 11, 1994.

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UBUS1 KWBC 112044
 IL 112044
SPI UUA /OV CAP001001/TM 2018/FL 002/TP AT42/TB LLWS/RM  + -10 KTS

UBUS1 KWBC 112044
 OH 112044
BKL UA /OV BKL/TM 2010/FL005/TPG3/TB LLWS +/- 10 KTS FA
CAK UA /OV CAK-CAK 235012/TM 2015/FL085/TP BE35/TB LGT-MDT BLO
067/RM DURGC CAK

UBUS1 KWBC 112044
 WI 112044
GRB UUA /OVGRB/TM 2040/FL002/TP HS25/TB LLWS -10-15 KTS/RM FNL RY 36
LSE UA /OV LSE/TM 2028/FL100/TP MU2/TB MDT 100-SFC
```

Figure 5a. Pilot reports of LLWS and significant turbulence from 2000 UTC 11 May 1994 to 0000 UTC 12 May 1994 in Illinois, Ohio and Wisconsin.

```
UBUS1 KWBC 112100
 WI 112100
GRB UUA /OV GRB/TM 2017/FL002/TP DC9/TB LLWS +10/-5 200 FEET
AGL/RM FA RY36
GRB UUA /OV GRB/TM 2035/FLUNKN/TP C414/TB LLWS -10/+5 KT/FA
RY36
MKE UUA /OV MKE 330008/TM 2039/FL020/TP PA28/T OCNL SVR
RHI UA /OV RHI180020/TM 2042/FL050/TP C182/TB MDT

UBUS1 KWBC 112124
 MI 112124
PTK UA /OV PTK/TM 2105/FLUNKN/TP PAYE/TB LGT-MDT BLO 80/RM
DURC
TVC UUA /OV TVC/TM 2100/FLDURD/TP C310/TB OCNL LGT CHOP
070/MDT OCNL SVR BLO 025/RM LLWS +/- 20 KTS BLO 2000 FT AGL
FA RY36

UBUS1 KWBC 112200
 WI 112200
GRB UUA /OV GRB/TM 2205/FLUNKN/TP BE40/RM LLWS +/- 15 KT AT 100 AGL
FA36

UBUS1 KWBC 112224
 OH 112224
MFD UUA /OV MFD 330030/TM 2213/FL070/TP BE58/TM MDT-SVR/RM HVY R

UBUS1 KWBC 112224
 PA 112224
IPT UUA /OV IPT/TM 2219/FL010/TP SH36/TB MDT/RM LLWS +/- 10K DURGC IPT
RWY 27

UBUS1 KWBC 112324
 NY 112324
FRG UUA/OV DPK246006/TM 2315/FL008/TP C172/RM LLWS -08KT FAP19 FRG
GFL UA /OV FAIRB/TM 2317/FL 080/TP C172/TB LGT-MDT
ROC UUA /OV FAP 22/TM 2317/FL010/TP E120/TB LLWS -15KNTS 010 TO SFC
```

Figure 5b. Additional pilot reports of LLWS and significant turbulence from 2000 UTC 11 May 1994 to 0000 UTC 12 May 1994 in Ohio, Wisconsin, Michigan, Pennsylvania and New York.

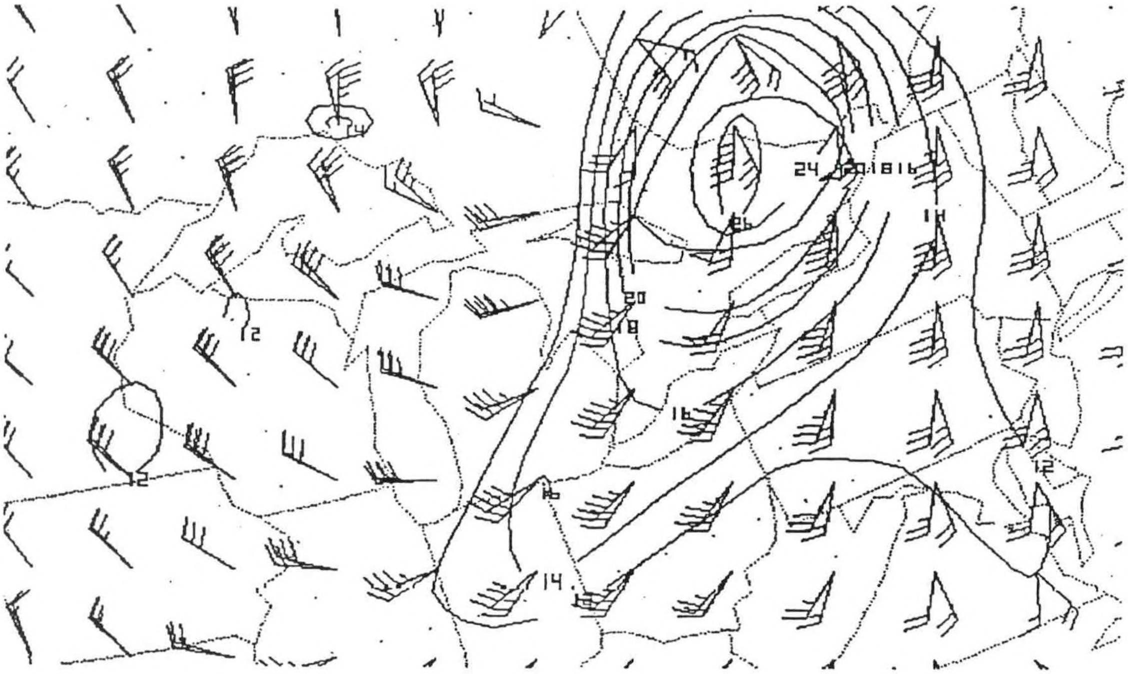

Figure 6a. LLWS flag contours (kts) valid 0000 UTC 12 May 1994. NGM 12-hour forecast from 1200 UTC gridded model output May 11, 1994.

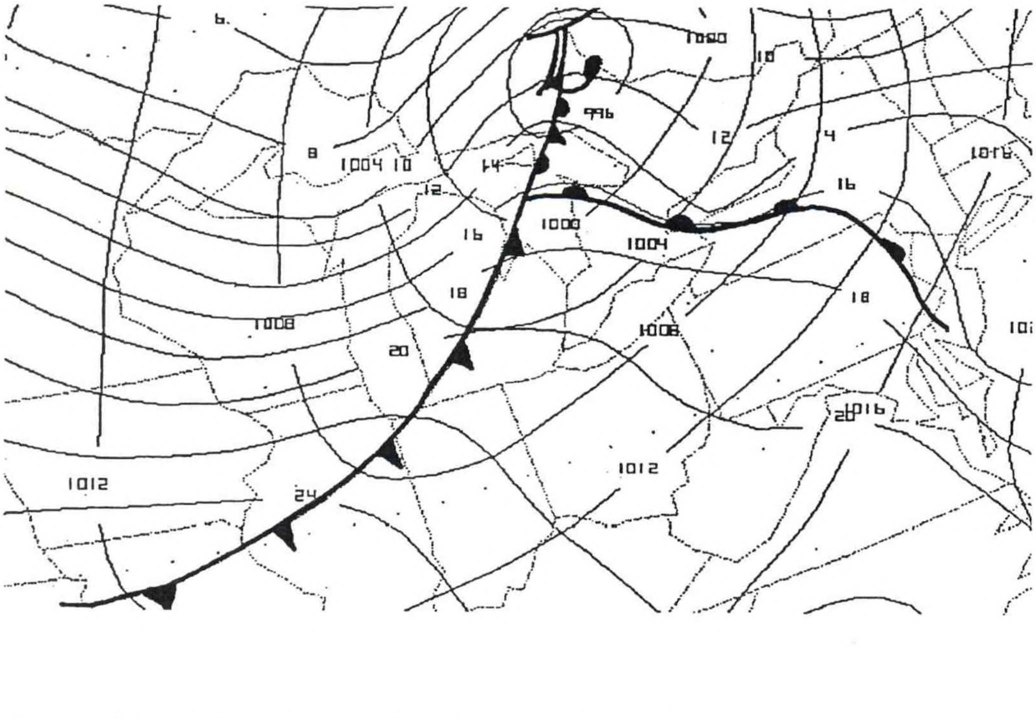

Figure 6b. Sea level pressure (mb), isotherms (°C) and subjectively analyzed frontal system forecast for 0000 UTC 12 May 1994. From NGM 12-hour gridded model output forecast from 1200 UTC 11 May 1994.

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UBUS1 KWBC 120000
 NY 120000
SYR UUA /OV GGT-SYR/TM 0009/TP PA32/TB MDT-SVR 50 AND BLO

UBUS1 KWBC 120100
 MI 120100
DET UA /OV DET/TM 0031/FLDURD/TP PA31/TB MDT 005-SFC/RM FA
RY25 500 AGL-SFC
DET UA /OV DET/TM O100/FL 025/TP SW4/TB LGT CHOP/RM LLWS +/- 5KTS
FAP/ALSO MU2

UBUS1 KWBC 120144
 NY 120144
UCA UUA /OV UCA/TM 0130/FL FAP15/TP BANDIT/RM LLWS +/- 5
KT/TB LGT-MDT CHOP FM 160-TCHDWN
UCA UA /OV UCA/TM 130/FL120/TP BE02/IC LGT RIME/TB 80-40 LGT+MDT BLO
40

UBUS1 KWBC 120200
 NJ 120200
TEB UUA /OV TEB 000000/TM 0210/FLUNKN/TP C650/RM LLWS +/- 5 KNTS FAP

UBUS1 KWBC 120200
 PA 120200
IPT UUA /OV LVZ/TM 0138/FL007/TP SHD3/TB LGT-MDT/RM LLWS +/- 15KT FA27
IPT

UBUS1 KWBC 120244
 IL 120244
DPA UUA /OV DPA 135035-DPA/TM 0234/FLDRGD/TP PARO/TB MDT-SVR 030-
014/RM HEAD HITTING ROOF
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Figure 7. Pilot reports from New York, Michigan, New Jersey, Pennsylvania and Illinois, received after 0000 UTC 12 May 1994.

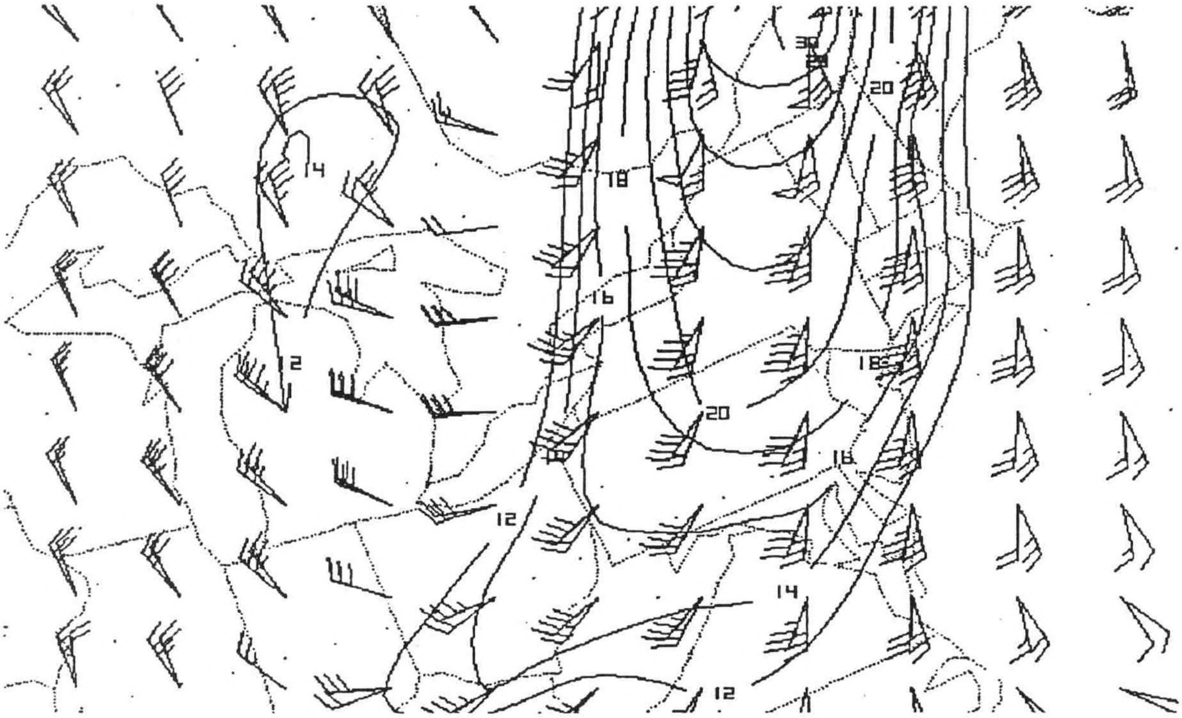

Figure 8a. LLWS flag contours (kts) valid 0600 UTC May 12 1994. NGM 18-hour forecast from 1200 UTC gridded model output May 11, 1994.

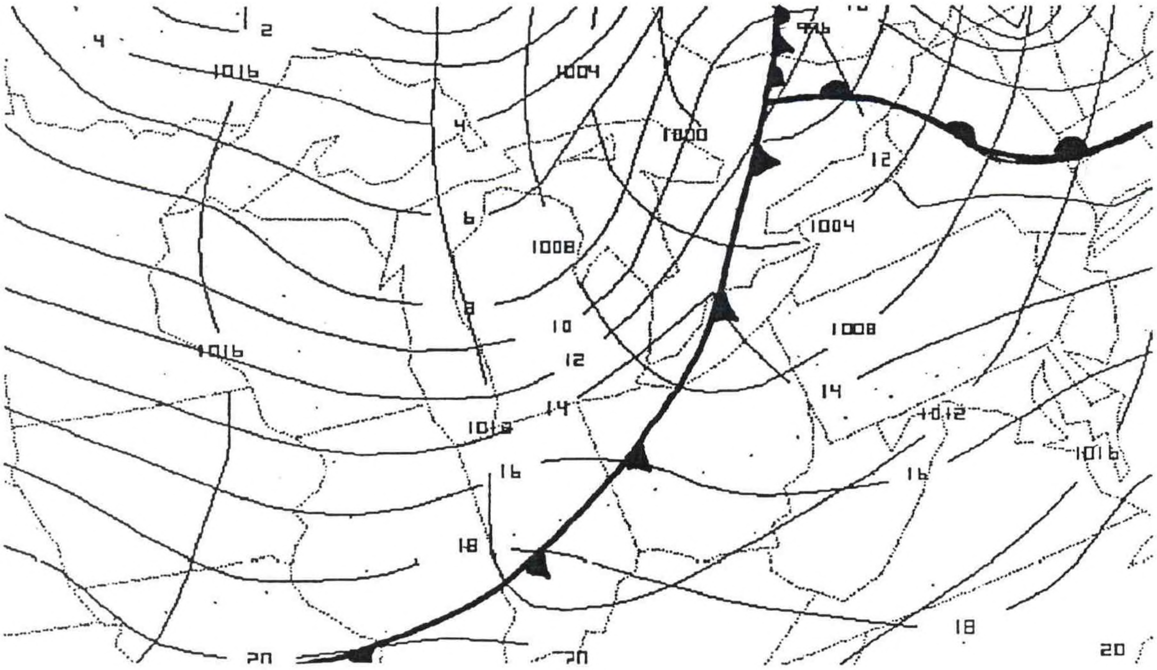

Figure 8b. Sea level pressure (mb), isotherms (°C) and subjectively analyzed frontal system forecast for 0600 UTC 12 May 1994. From NGM 18-hour gridded model output forecast 1200 UTC 11 May 1994.

The technique had shown that a synoptic model reasonably depicted a well documented mesoscale event. However, another case was desired to reinforce the findings. It was not long before that case presented itself. The 0000 UTC NGM model run of May 14 predicted a fast moving cold front sliding off the southern New England coast with a stationary front setting up across western New York at 1200 UTC 14 May. LLWS "flag" contours indicated a shear area behind the front from northern Maine to eastern New York (Figure 9a and 9b). Several pilot reports from Vermont to Connecticut in the hours from 1200 UTC to 1400 UTC indicated moderate to severe turbulence and +/- 20 knot LLWS over southwest Connecticut. Occasional LLWS pireps continued through about 1600 UTC (Figure 10).

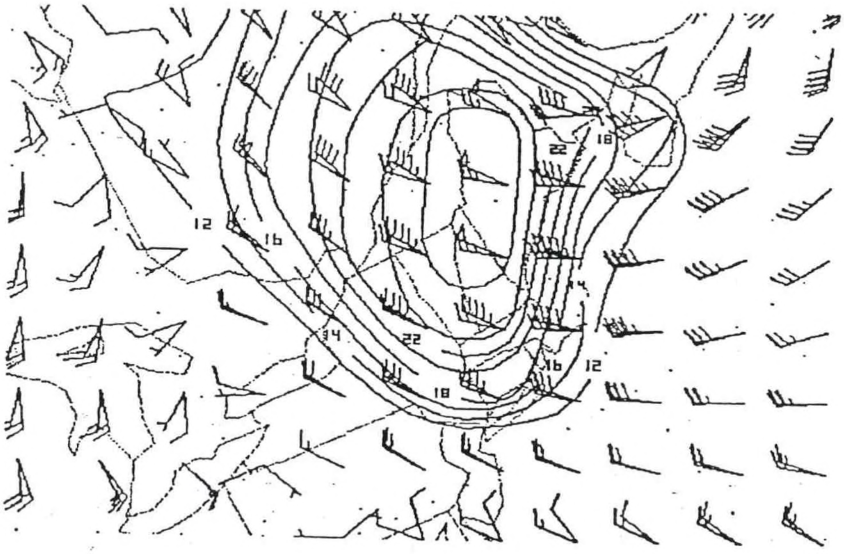

Figure 9a. LLWS flag contours (kts) valid 1200 UTC 14 May 1994. NGM 12-hour forecast from 0000 UTC gridded model output May 14, 1994.

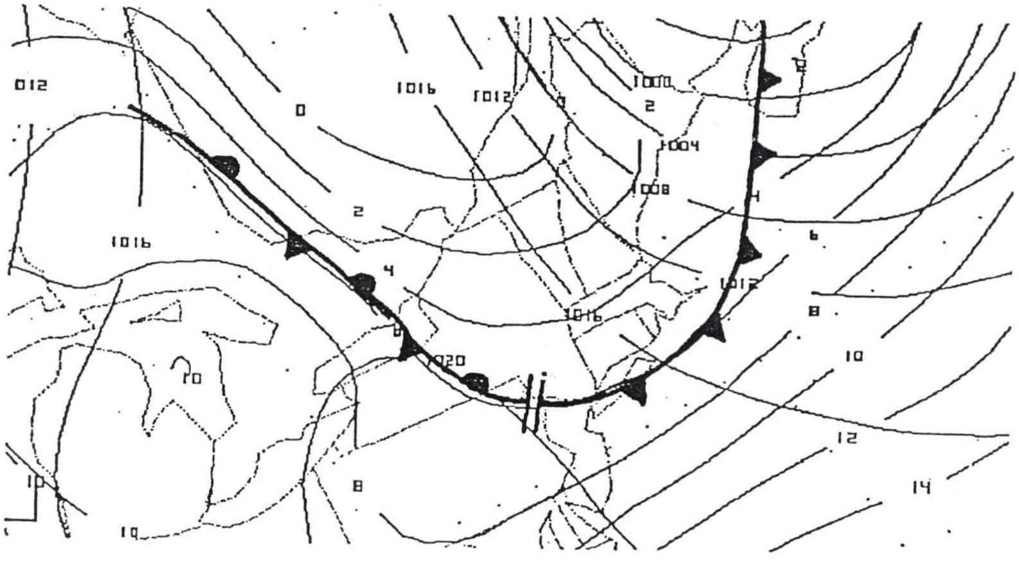

Figure 9b. Sea level pressure (mb), isotherms (°C) and subjectively analyzed frontal system forecast for 1200 UTC 14 May 1994. From NGM 12-hour gridded model output forecast 0000 UTC 11 May 1994.

Corrected copy

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 CT
HVN UUA /OV HVN/TM 15255/FLDURD/TP PARO/TB MDT 035-015/RM LLWS
015-SFC SMTH 065-035
BDR UUA /OV BDR/TM 1316/FL020/TP C172/WX FV50+/TB MDT OCNL SVR
DXR UUA /OV DXR/TM 1327/FL050/TP AA5/TB NEG/LGT-MDT 020-040/RM LLWS
+/- 20KTS SFC-020
DXR UA /OV CMK045023/TM 1318/FL055/TP PA22/RM STG UP DRFTS
DXR UUA /OV DXR/TM 1323/FLDURD/TP AA5/RM LLWS +-20KTS BLO
020 FAP RY35

 NH
ASH UUA /OV ASH 270015/TM 1200/FL050/TP PA28/TB MDT-SVR/RM 50-BLO
LEB UA /OV LEB360005/TM 1240/FL045/TP MO20/TB MDT-SVR/NEG 055-065

 VT
RUT UUA /OV DURGD/TM 1213/FL035/TP C208/TB SVR BLO 035

 MA
BED UA /OV BED-ACK/TM 1259/FL030/TP C152/TB CONT LGT BLO 030
BED UUA /OV BED/TM 1250/FLDURD/TP C172/TM LLWS -10KTS FAP
RY29
HYA UUA /OV HYA 180002/TM 1312/FLDURC/TP PA28/TB LGT 010-020/MDT-SVR
025
```

Figure 10. Pilot reports from Connecticut, Vermont, Maine and New Hampshire. 1200 UTC through 1550 UTC 14 May 1994 (Obtained from Direct User Access Terminal- DUAT).

4. Conclusions

In a low level wind shear forecast test dealing with synoptic scale features, Richwien and McLeod (1978) concluded that potentially dangerous low level wind shear conditions result from meteorological features smaller than synoptic scale, and charts representing synoptic scales of motion are of little value for identifying LLWS. With the finer resolution of the NGM gridded model output and analysis tools like PCGRIDDS, meteorologists are beginning to more easily link synoptic scale motions with "features smaller than synoptic scale".

This paper does not attempt to make any dynamical links between the two scales of motion, and was intended to demonstrate how the present day technology is making it easier to identify the background flow which may lead to mesoscale LLWS. Therefore, this PCGRIDDS macro should be used as an alert technique for aviation forecasters to identify potential synoptic wind shear environments well in advance of the event. As the valid time approaches, the forecaster is more readily aware of the situation, and can spend more time analyzing the mesoscale features that will be generated by the environment. The WSR-88D and wind profiler networks are proving to be excellent tools for this analysis. As mesoscale models, like the Rapid Update Cycle, become more readily available, a similar macro or algorithm should be even more effective in predicting LLWS. As with all model guidance, the results of this LLWS analysis are only as good as the model verification.

5. Acknowledgements

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6. References

Badner, J., 1978: Low level wind shear. NOAA Technical Memorandum NWS-FCST-23.. DOC/NOAA/NWS/Office of Meteorological Operations, Weather Analysis and Predicition Division, Silver Spring, MD, 57pp.

DOC, NOAA, and NWS, 1994: NWS Operations Manual. Aviation Terminal Forecasts, Part D, Chapter 21, Silver Spring, MD, 61pp.

Jannson, D., 1981: Low Level Vertical Wind Shear and Temperature Inversions Observed at Sudsvall Aerodrome. *Zentralanstalt fur Meteorologie und Geodynamik Pub.* **253**, 197-201.

Meier, K.W., 1993: PCGRIDDS User's Manual. Department of Commerce, 26pp.

Richwien, B.A., and R. McLeod, 1978: Low Level Frontal Windshear Forecast Test. FAA Report No. FAA RD-77-184, 24pp.

Wachtmann, R., 1978: Low Level Frontal Wind Shear Test. AWS Aero. Sci. Rev, (Draft Report).