TECHNIQUES SUITABLE FOR FORECASTING PRECIPITATION TYPES

USING NWP MODEL OUTPUT

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1. ABSTRACT

A simple method for discriminating precipitation types during the winter season is presented. The scheme is based strictly on vertical temperature profiles and has been previously documented in NWS TPB101 (1973).

Using specialized graphical displays, a few freezing rain cases taken from the 1985-86 1986-87 winter seasons are studied. Direct model output from the Canadian RFE model is fed as input to the scheme.

The simplicity of the method coupled to graphical representation allows rapid 3-D interpretation of the detailed internal structure of winter storms. These prove to be useful as real-time forecast guides.

2. INTRODUCTION

With the acquisition of vector computers, the CMC has substantially increased its data processing capacity over the past few years. This technology has also allowed the development of sophisticated graphic systems and the use of several unconventional outputs of numerical forecasting models.

In this article, we like to present new numerical guides that could help regional meteorologists working on forecasting winter weather.

3. IMPROVEMENT IN NUMERICAL MODELS

One of the major problems related to winter forecasting consists in clearly specifying the types of precipitation in the various regions affected by a storm.

For several years now, much of the research in NWP has centred on coupling atmospheric boundary layer models to large-scale forecasting models. These efforts have led to the introduction at the CMC of a regional model (EFR) with increased resolution concentrated in the lower troposphere (1).

This increased resolution leads us to believe that we can now better forecast the details of the vertical atmospheric structure and, consequently, improve the forecasting of winter weather elements.

4. CHOICE OF A TECHNIQUE

The approach generally used to determine the types of precipitation assumes that precipitation originates in solid form (snow crystals) from an upper layer of the atmosphere. Alternating warm and cold layers bring phase changes that transform the snow into (freezing rain/sleet/rain).

A technique based on this approach was considered by the U.S. National Weather Service in 1973 (2). We believe that the vertical resolution in the CMC's operational models is now sufficient to allow us to use this technique (Appendix 1).

5. DATA USED

For several years, the data bases generated by the CMC's numerical models have contained meteorological variables at standard pressure levels (1000, 850, 700, 500...) mb. Other data bases containing forecasts projected directly onto the models' sigma levels are now saved on disk. Because of better vertical resolution, we believe that the latter data banks are superior to the former.

In addition, the vertical resolution of the current analyses at the CMC is substantially below that of the operational models in the lower atmospheric levels (4 levels below 500 mb vs 11 for the EFR model and 7 for the v9 model). As a result, our models initially lack details on the atmosphere's vertical structure. It is well established that in the first hours of integration, models adjust to solutions proper to their own resolution and are able to generate mesoscale circulations not found in their initial states (3). For this reason, we selected 12-hour forecasts of the EFR model to evaluate our scheme.

6. ALGORITHM USED

The scheme described under (2) is based on the relative depth between various warm and cold layers in the atmosphere:

i.e.: Warm layer: atmospheric layer where $T \geqq 0$ degree
Cold layer: atmospheric layer where $t \leqq 0$ degree

To estimate these quantities, we:

a) obtain Z (height in dam) | for $\sigma = (0.1, \ldots 1.0)$
obtain T (temperature in °C) |

b) find pairs of sigma levels where $T(\sigma)$ changes sign.

c) estimate freezing levels by linear interpolation.

d) find the precipitation type by applying the criteria given in (2). (See appendix 1).

7. STUDY OF THE MARCH 13, 1986 STORM

7.1 Synoptic situation

The CMC surface analysis (Figure 1) on the morning of March 13, 1986, showed a low over Iowa with a warm front stretching eastward over the Great Lakes. A cold air ridge covered northern Ontario and Québec. A band of (sleet/freezing rain) extended from Minnesota to the eastern coast of the United States.

A comparison with the objective analyses (Figure 2) and corresponding EFR forecasts (Figure 3) shows that meteorological fields were generally well predicted. It is noted, however, that the model was a little toc fast and that it carried warm air slightly too far north.

The vertical cross-section (temperature vertical motion) (Figure 4) gives us a better understanding of the atmospheric circulation around the frontal zone located over the Great Lakes. We note in particular that there is:

1. a subsidence of cold air north of the frontal zone.
2. an uplift of warm air and precipitation over the frontal zone.
3. a warm layer above a cold layer in front of the frontal zone.

7.2 Comparison (Scheme/Observations)

An analysis of the types of precipitation on the morning of March 13, 1986 (Figure 1) shows that a snowfall area extended from Kansas to the north of lakes Michigan and Huron, and covered the centre of New York State as well as southern Vermont. A precipitation band (freezing rain/sleet) some 100 km wide was found south of this area. Rain covered the south of Michigan, southern Ontario and the western part of the state of New York.

To compare the forecasts produced by our scheme with this analysis, we drew a similar chart on the computer by using the data from the algorithm (section 6) and applying it to forecasts from the EFR model.

By examining these two charts (Figures 1 and 5) we note that there is a good correlation between predicted and observed precipitation patterns. Differences are attributable in part to forecast errors by the model, which predicted a slightly too rapid advance of the meteorological system.

8. SUMMARY AND CONCLUSIONS

In the previous sections, we showed precipitation forecasts made with a simple scheme based on vertical profiles predicted by a numerical model. The purpose of this exercise was not to make an exhaustive evaluation of the forecasts derived from this algorithm but rather to show operational meteorologists the type of products that we are able to support with the computer resources we currently have.

A real-time study of forecasts produced by this scheme during the winter of 1986-87 leads us to believe that a more quantitative evaluation should be made during the next winter season. This evaluation could be made together with meteorologists from a regional weather office.

REFERENCES

1. Benoit, Robert: Une description de la physique ainsi qu'une vue d'ensemble du modèle régional canadien aux éléments finis. CMC document technique, No. 28, janvier 1987.

2. Experimental forecasts of freezing level(s), conditional precipitation type, surface temperature and 50-meter wind, produced by the boundary layer (PBL) model. Technical procedures bulletin no. 101, November 1973.

3. Warner, Thomas T.: The initialization of mesoscale models. Proceedings of the nowcasting-II symposium, Norkopping, Sweden (1984).

LEGENDS OF FIGURES

Figure 1) Preliminary surface analysis (CMC) valid at 12Z March 13, 1986.

Figure 2a) 500 mb objective analysis valid at 12Z March 13, 1986.

Figure 2b) MSL objective analysis valid at 12Z March 13, 1986.

Figure 2c) 850 mb objective analysis valid at 12Z March 13, 1986.

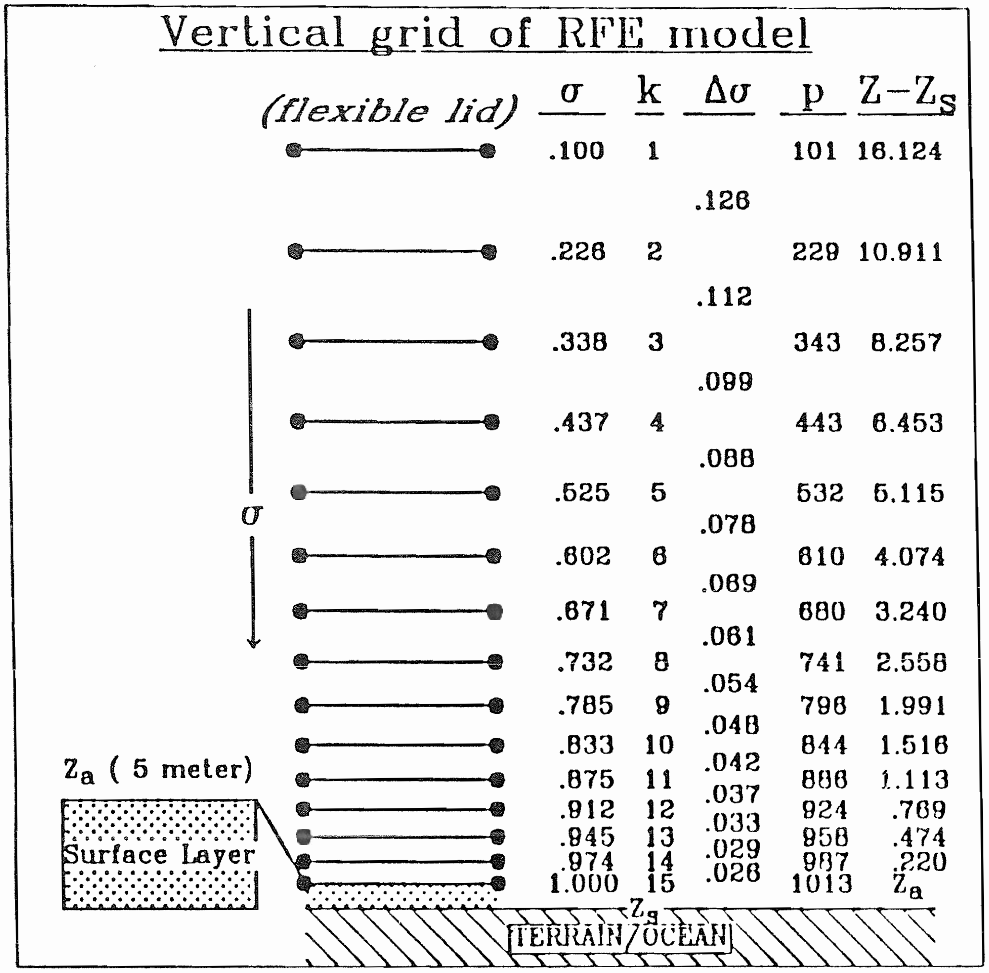
Figure 3a) 500 mb (EFR) 12-hour forecast valid at 12Z March 13, 1986.

Figure 3b) MSL (EFR) 12-hour forecast valid at 12Z March 13, 1986.

Figure 3c) 850 mb (EFR) 12-hour forecast valid at 12Z March 13, 1986.

Figure 4) Vertical cross-section (Vertical motion w(μb/s) - Temperature (°C)) derived from a 12-hour forecast (EFR) valid at 12Z March 13, 1986.

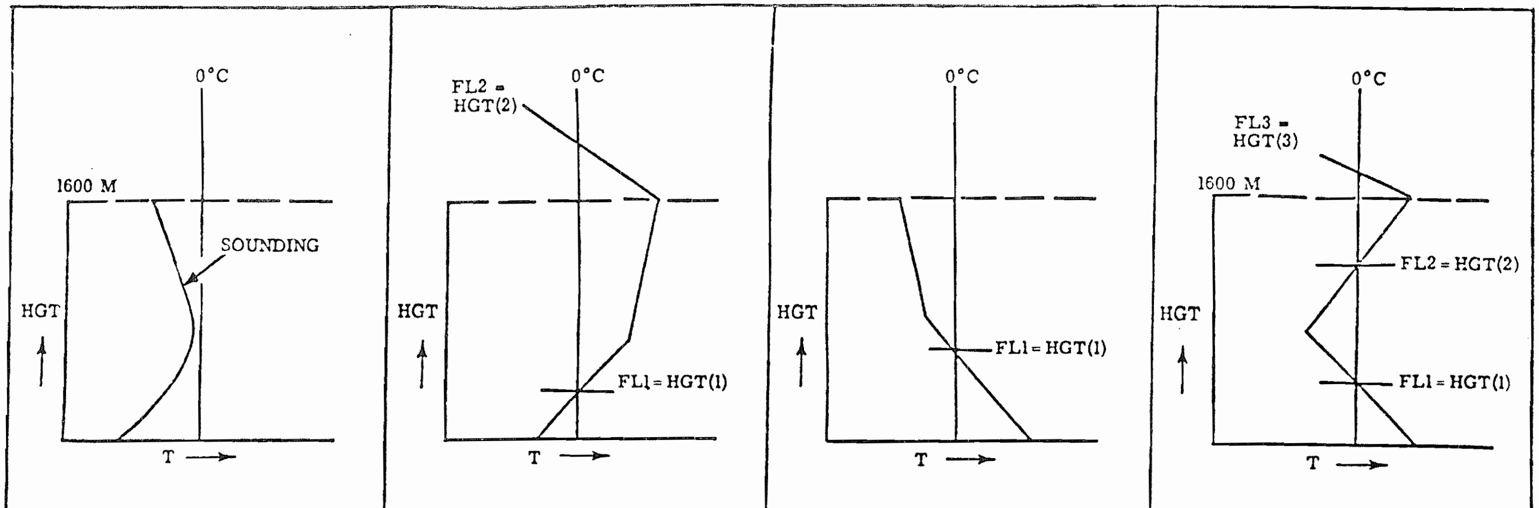
Figure 5) Precipitation types forecast derived from the algorithm of section 6.



APPENDIX 1 (TAKEN FROM REFERENCE 1)

Vertical distribution of levels for the model. σ is pressure normalized by the surface pressure. Levels are indexed (K) top down. Spacings ($\Delta\sigma$) are given, as well as nominal pressure (p, mbar) and elevation above terrain ($Z-Z_s$, km); the ICAO atmosphere was used. Fluid is confined by a flexible lid at top and by a shallow (Z_a= 5m) turbulent surface layer near ground or ocean.

APPENDIX 1 (TAKEN FROM REFERENCE 2)



FREEZING LEVEL — SFC Below Freezing (BF)	Freezing Level 2 = FL2 = HGT(2) Freezing Level 1 = FL1 = HGT(1) SFC BF	Freezing Level 1 = FL1 = HGT(1)	Freezing Level 3 = FL3 = HGT(3) Freezing Level 2 = FL2 = HGT(2) Freezing Level 1 = FL1 = HGT(1)

PRECIP TYPE — Snow (S)	If FL1 > 1000' and (FL2-FL1) > 500' = Sleet (E)
	If FL1 < 1000' and (FL2 − FL1) > 500' = Freezing Rain (Z)
	If (FL2-FL1) < 500' = Snow (S)
		If FL1 < 2000 FT = Mixed Rain/Snow (M)
		If FL1 > 2000 FT = Rain (R)
			If (FL3-FL2) < 500' and FL1 < 1200 FT and SFC Temp < 36°F = Snow (S)
			If (FL3-FL2) > 1000' and (FL2-FL1) > 500' and FL1 < 1000' = Sleet (E)
			If (FL3-FL2) < 500' and FL1 > 1200' = Rain (R)
			If (FL3-FL2) > 500' and < 1000' and (FL2-FL1) < 500' and FL1 > 1000' = Mixed Rain/Snow (M)

Derivation of the freezing level(s) and conditional precipitation type

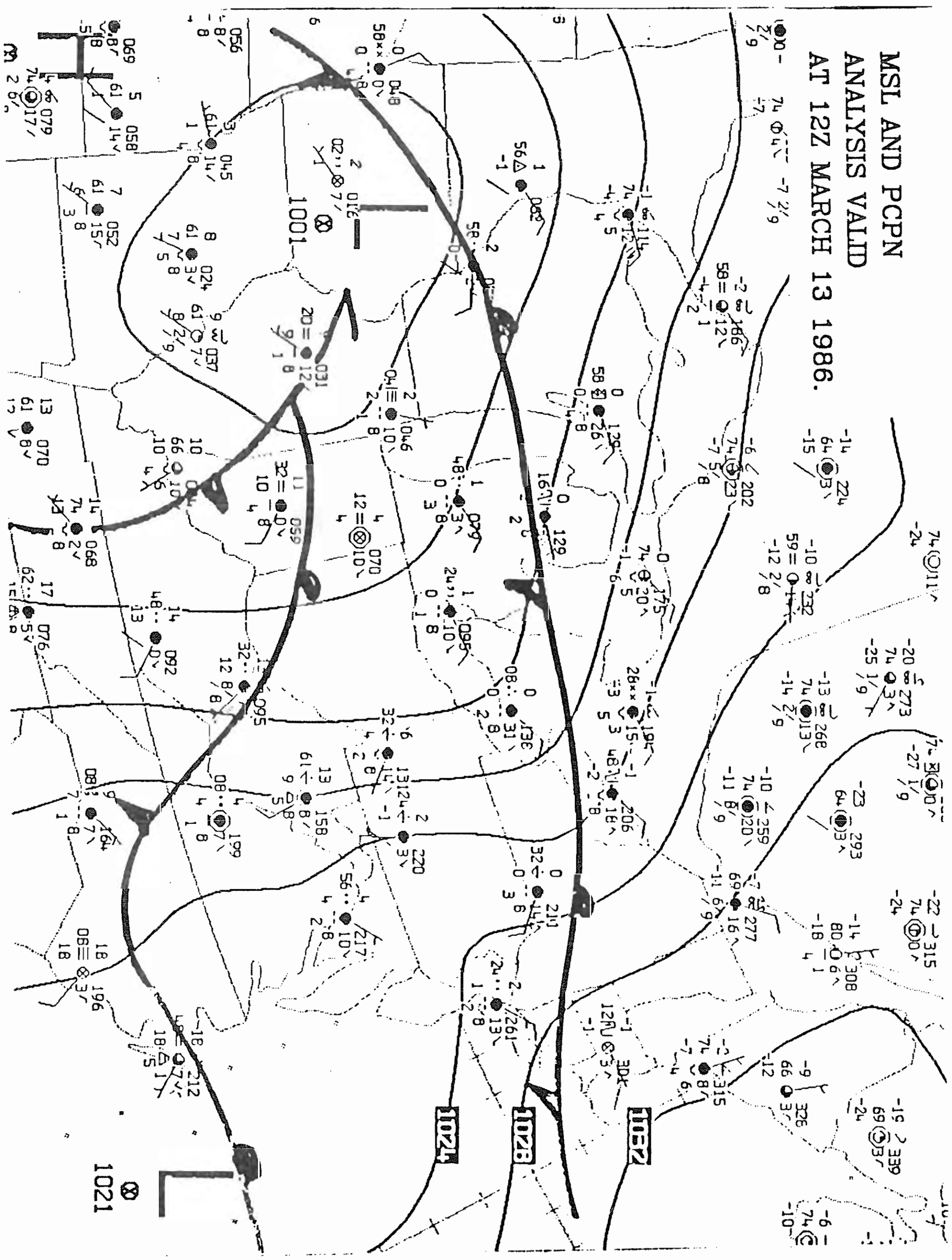
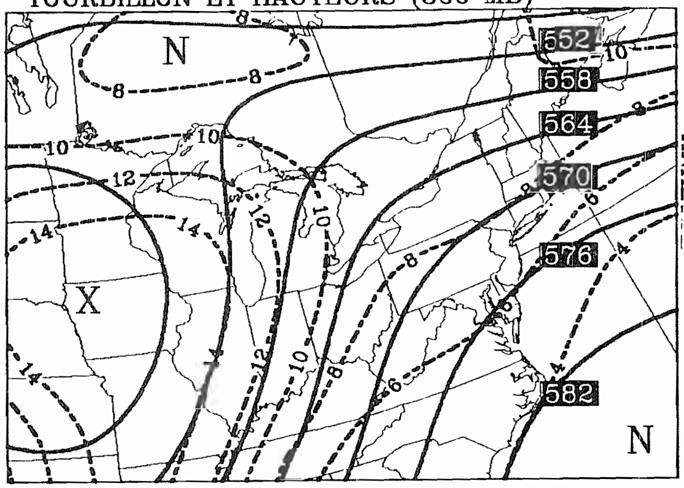


FIGURE 1

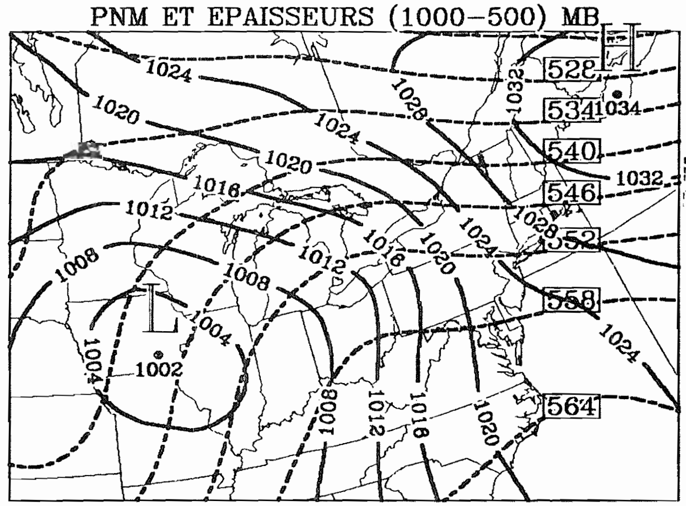
MSL AND PCPN ANALYSIS VALID AT 12Z MARCH 13 1986.

FIGURE 2

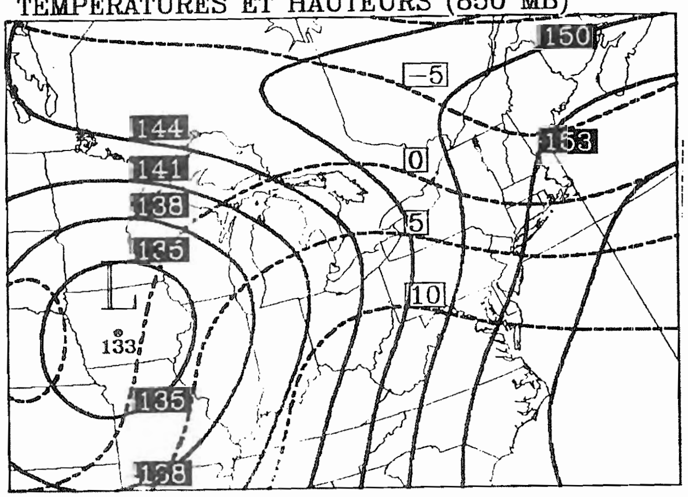
2a) TOURBILLON ET HAUTEURS (500 MB)



2b) PNM ET EPAISSEURS (1000–500) MB



2c) TEMPERATURES ET HAUTEURS (850 MB)

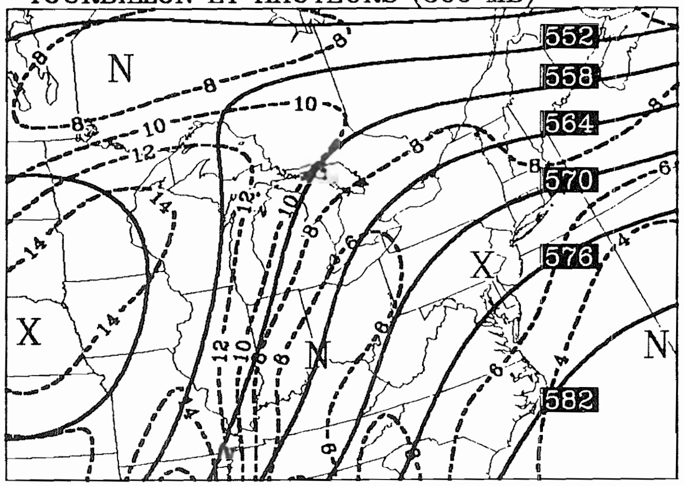


ANALYSIS VALID
AT 12Z MARCH 13 1986.

FIGURE 3

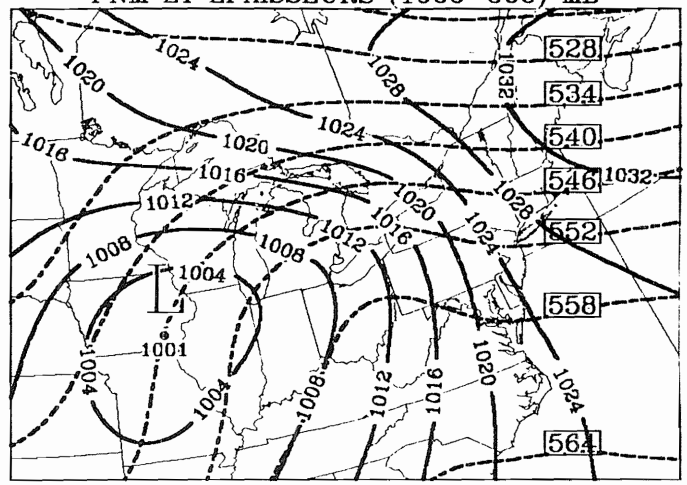
3a)

TOURBILLON ET HAUTEURS (500 MB)



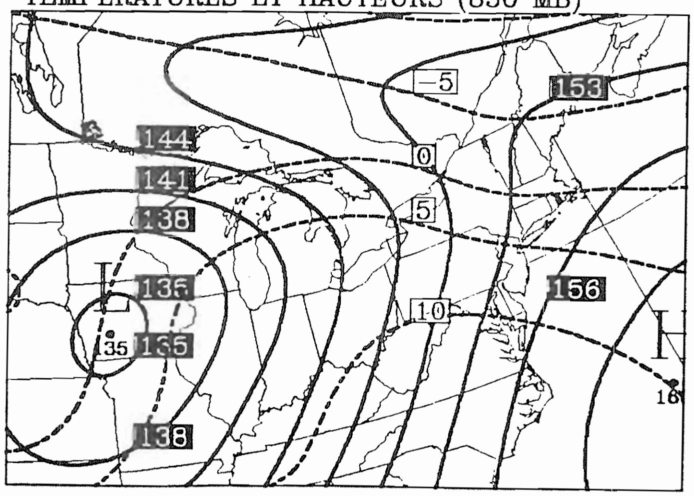
3b)

PNM ET EPAISSEURS (1000–500) MB



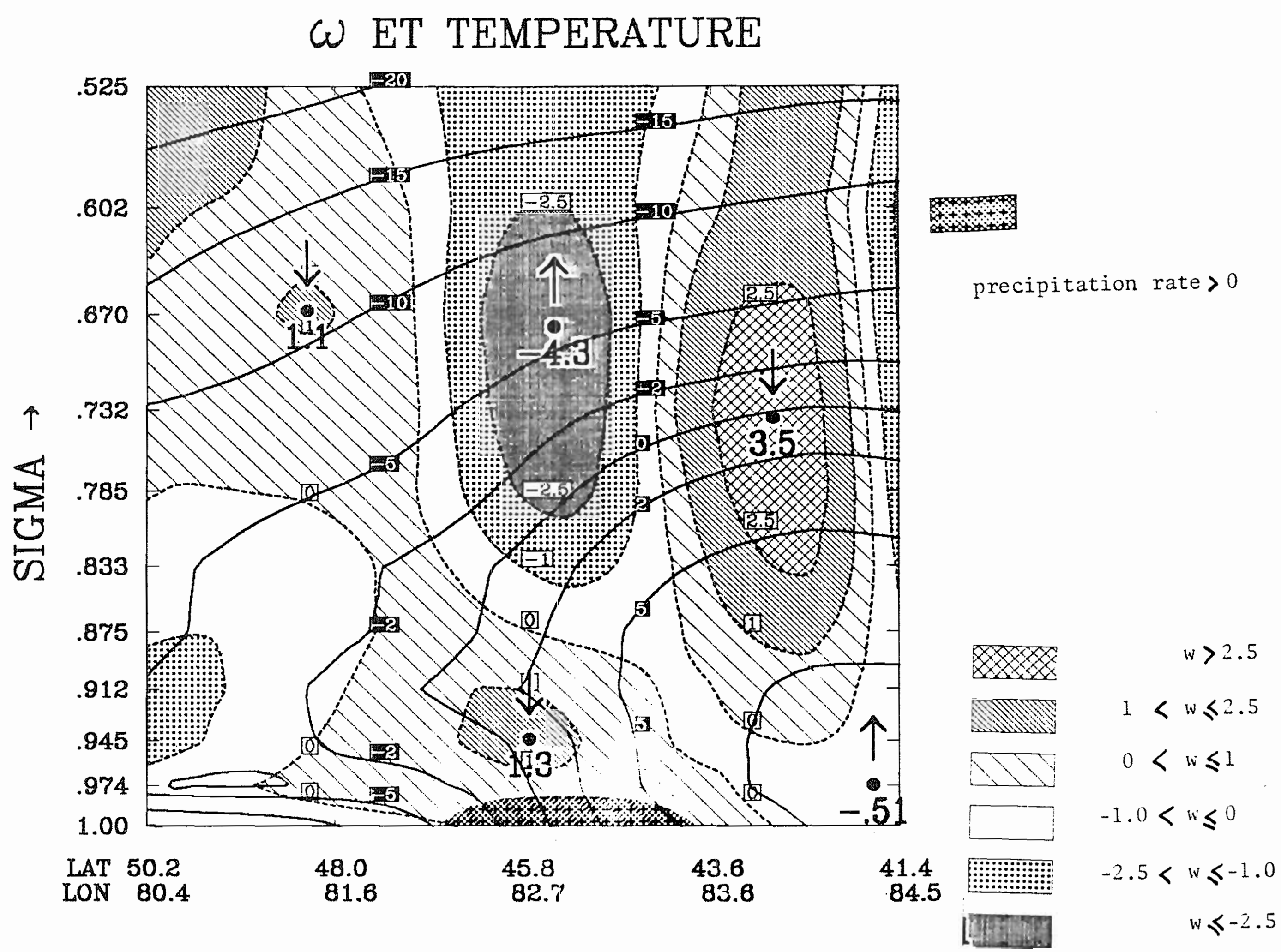
3c)

TEMPERATURES ET HAUTEURS (850 MB)



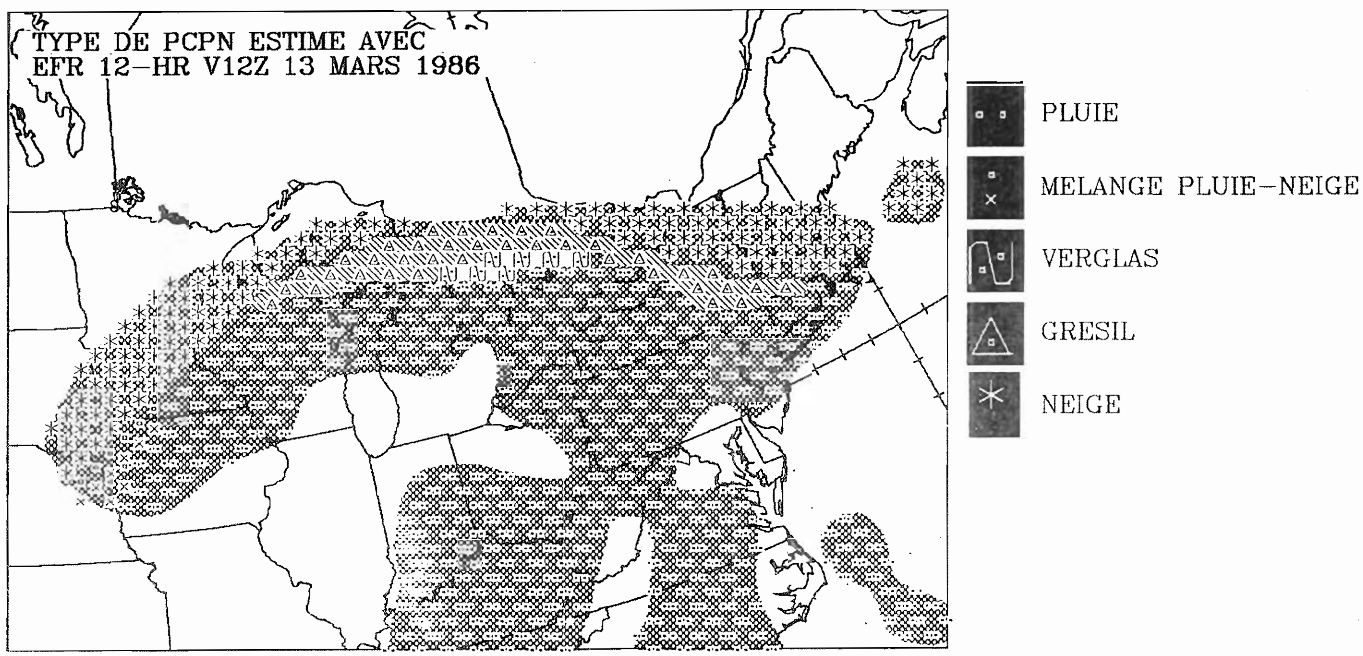
12HR EFR FORECAST VALID
AT 12Z MARCH 13 1986.

FIGURE 4



ω ET TEMPERATURE
SIGMA →
.525
.602
.670
.732
.785
.833
.875
.912
.945
.974
1.00
LAT 50.2 48.0 45.8 43.6 41.4
LON 80.4 81.6 82.7 83.6 84.5
1.1
-4.3
3.5
1.3
-.51
precipitation rate > 0
w > 2.5
1 < w ≤ 2.5
0 < w ≤ 1
-1.0 < w ≤ 0
-2.5 < w ≤ -1.0
w ≤ -2.5

FIGURE 5


TYPE DE PCPN ESTIME AVEC
EFR 12-HR V12Z 13 MARS 1986
PLUIE
MELANGE PLUIE-NEIGE
VERGLAS
GRESIL
NEIGE