NOAA Western Region Computer Programs and
Problems NWS WRCP - No. 21

FREEZING LEVEL PROGRAM

Salt Lake City, Utah
September 1980

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

PREFACE

This Western Region publication series is considered as a subset of our Technical Memorandum series. This series will be devoted exclusively to the exchange of information on and documentation of computer programs and related subjects. This series was initiated because it did not seem appropriate to publish computer program papers as Technical Memoranda; yet, we wanted to share this type of information with all Western Region forecasters in a systematic way. Another reason was our concern that in the developing AFOS-era there will be unnecessary and wasteful duplication of effort in writing computer programs in National Weather Service (NWS). Documentation and exchange of ideas and programs envisioned in this series hopefully will reduce such duplication. We also believe that by publishing the programming work of our forecasters, we will stimulate others to use these programs or develop their own programs to take advantage of the computing capabilities AFOS makes available.

We solicit computer-oriented papers and computer programs from forecasters for us to publish in this series. Simple and short programs should not be prejudged as unsuitable.

The great potential of the AFOS-era is strongly related to local computer facilities permitting meteorologists to practice in a more scientific environment. It is our hope that this new series will help in developing this potential into reality.

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Great Falls, Montana

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UNITED STATES
DEPARTMENT OF COMMERCE
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NATIONAL OCEANIC AND
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Service
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FREEZING LEVEL PROGRAM

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I. General Information

A. Summary:

This program computes the freezing level (MSL) for any station through the use of/or interpolation of actual data or by extracting the data from numerical model data. This is accomplished by only three input parameters, sea-level pressure, 700-mb height and 500-mb height. Useful by-products of this program, especially when using the numerical progs, are the predicted 850-mb, 700-mb, and 500-mb temperatures.

B. Environment:

The program is completely integrated into AFOS; no procedure is needed to run the program. Data are input on the AFOS ADM command line (line 25) and results are automatically sent back to the ADM screen at program completion. The program is written in FORTRAN and is run on the DATA GENERAL ECLIPSE S/230 computer.

C. References:

1. Mollner, Mark A., and Olsen, David E., 1978: Automated Fire Weather Forecasts, Western Region Technical Memorandum WR-131, National Weather Service Western Region, NOAA, Salt Lake City, Utah.

2. Mielke, Kenneth B., 1979: A Computer Program for Convective Parameters, National Weather Digest, Vol. 4, No. 3, pp 10-18.

3. Berry, F. A., Jr., Bollay, E., and Beers, Norman R. (Editors), 1945: Handbook of Meteorology. McGraw-Hill Book Company, New York and London, pp 343, 362-371, 376-377.

4. Inman, Rex L., 1969: Computations of Temperatures at the Lifted Condensation Level. Journal of Applied Meteorology, Vol. 8, No. 1, p 157.

II. Application

In computing the freezing level, this program first determines the temperatures at the 850-mb, 700-mb, and 500-mb levels, producing an approximation of the sounding. Lapse rates between these levels are then computed which are used to find the intersection of the sounding with the 0°C isotherm. If significant precipitation occurred or is expected to occur during the preceding 12 hours, the program is directed to a subroutine which computes the wet-bulb temperatures at the 850-mb and 700-mb levels, which will better approximate the sounding. This is accomplished by inputting the 700-mb and 500-mb height in meters and the sea-level surface pressure.

The hypsometric equation is utilized extensively in this program.

$$\Psi_2 - \Psi_1 = \frac{R\,\overline{T}^*}{9.8} \ln \frac{P_1}{P_2} \qquad [1]$$

where Ψ_1, Ψ_2 = height in geopotential meters at P_1 and P_2.

R = universal gas constant for dry air .28704 j/g°K.

P_1 , P_2 = pressure (mb) at Ψ_1 and Ψ_2.

$\overline{T}^*$ = average virtual temperature.

It has been shown (Mollner and Olsen, 1978) that an accurate 700-mb and 850-mb temperature can be obtained using the hypsometric equation. This is accomplished by solving for the virtual temperature and assuming that the 850-mb - 700-mb levels fall midway between the input 700-mb - 500-mb heights (m), respectively, and the input sea-level surface pressure.

A similar approach is used in this paper. Therefore, the temperature equations for the 850-mb and 700-mb levels became:

$$T85 = \left(\frac{H7 \cdot 9.8}{R \cdot \ln P_s/_{700}}\right) - 273 + E1 - 1 \qquad [2]$$

$$T70 = \left(\frac{H5 \cdot 9.8}{R \cdot \ln P_s/_{500}}\right) - 273 \; -1 \qquad [3]$$

where H7 = 700-mb height geopotential meters (gpm)
H5 = 500-mb height (gpm)
P_s = surface pressure (mb)
$E1 = 2\left(\sin\left(\frac{(mo \cdot 30 + DA - 30)/2)}{57.286}\right)\right)^2$

where mo = month
DA = day of month.

In the case of the 850-mb temperature, a solar term is included (Mollner and Olsen, 1978) which more accurately depicts the 850-mb temperature, since it is more sensitive to solar insolation year around. This results in a maximum correction of +2°C on 1 July and a minimum correction of 0°C on 1 January. Also, since the virtual temperature is always slightly greater than or equal to the actual temperature, 1°C is subtracted from the virtual temperature calculations in this paper.

If significant precipitation has occurred or is expected to occur during the 12 hours preceeding the computation, it is assumed that the 850-mb and 700-mb temperatures are better approximated by the wet-bulb temperature due to evaporative cooling. In this case, the program is directed to a subroutine which computes the wet-bulb temperatures at the 850-mb and 700-mb temperatures.

Within this subroutine, the dew-point temperature at each level is first calculated using the dry bulb 850-mb and 700-mb temperatures calculated earlier and a relative humidity value assumed to be 80%. These values are incorporated into a version of the Clausius-Clapeyron Equation as follows:

$$t_d = \left[\frac{5420.51}{(5420.51) \cdot ((.00366) - 1/T + 273)) + LOG(.80) + 1.81 - 21.649} \right] -273 \qquad [4]$$

where T = Temperature at either 850 or 700 mb (°C).

The remaining steps in the subroutine follow closely the procedure shown by Mielke, 1979. First, an equation by Haurwitz (Inman, 1969) is used to derive a temperature at the Lifted Condensation Level (LCL).

$$t_{LCL} = t_d\,(.212 + .001571\, t_d - .000436\, t) \cdot D \qquad [5]$$

where t_d = dew-point temperature (°C)
t = temperature (°C)
D = dew-point depression

Then Poissons equation is used to find the pressure at the LCL.

$$P_{LCL} = P \left(\frac{T_{LCL}}{T_o} \right)^{CP/R} \qquad [6]$$

where P = initial pressure (mb)
T_o = initial temperature (°K)
T_{LCL} = temperature at LCL (°K)
C_p = specific heat at constant presssure

The procedure, so far, will have determined a temperature and pressure at the LCL for both the 850-mb and 700-mb levels. At this point, the parcel at each LCL must be brought back down to the original pressure level moist-adiabatically to determine the wet-bulb temperature.

A moist-adiabatic equation given by Haurwitz (as shown by Berry, et al, 1945) is utilized.

$$Y = \frac{RT}{CpP}\left(\frac{P + (.622\, L_v e_s/RT}{P + (.622\, L_v^2 e_s/CpRT^2}\right) \qquad [7]$$

where L_v = latent heat of vaporization (j/g)

e_s = saturation vapor pressure

and assuming $e \cong e_s$.

As given by Teten and as shown by Berry, et al, 1945:

$$e_s = 6.11\left(10^{at/(b + t)}\right) \qquad [8]$$

where a = 7.567
b = 239.9

The latent heat of vaporization is defined using a linear interpolation method (Mielke, 1979).

Using the above equations and starting at the LCL, the program then calculates a new temperature, subtracting 1 mb of pressure during each iteration until the original pressure level is reached (850 mb or 700 mb). This is then the wet-bulb temperature and is passed back to the main program.

Having solved the 850-mb and 700-mb temperatures, the hypsometric equation is again applied to compute the 500-mb temperature. Again, the equation is solved for the virtual temperature using the known values of the 500-mb and 700-mb heights.

$$VT_{700\text{-}500} = \left(\frac{(H5 - H7)\ 9.8\ R}{\ln {}^{700}/_{500}}\right) - 1 \qquad [9]$$

The 500-mb temperature can now be solved since the 700-mb temperature is already known, as follows:

$$T50 = (2 \cdot VT_{700\text{-}500} - (T70 + 273)) - 273 \qquad [10]$$

This, of course, assumes that the 700-mb temperature is reasonably accurate. It has been found, and will be shown later, that the 700-mb temperature can be accurately solved and, therefore, yields an accurate forecast of the 500-mb temperature as in (10) above.

After the 850-mb, 700-mb, and 500-mb temperatures are solved, the program determines between which two levels the freezing level is located. A lapse rate (°C/mb) is then computed for that layer. A program loop is then initiated at the bottom of the layer, for example 850-mb, and uses the computed 850-mb temperature as a starting point, then recomputes, using the

850-mb - 700-mb lapse rate, a new temperature at 1-mb increments. When this process intersects the 0°C isotherm, the freezing level, in millibars, is solved. If the freezing level is determined to be below 850 mb, the 850-mb - 700-mb lapse rate is then assumed to extend to the surface.

Now that the freezing level is solved in millibars, the hypsometric equation is used once more to convert the pressure surface to height (ft) above sea level. An assumption that a geopotential meter is approximately equal to a geometric meter is used.

$$FL = \left(\frac{\ln (Ps/P0)\ \overline{T^*}\ R}{9.8} \right) \cdot 3.28 \qquad [11]$$

where Ps = sea-level pressure (mb)
P0 = pressure at freezing level (mb)
3.28 = conversion (meters to feet)

The virtual temperature, in this case, is actually computed from the 850 mb to the freezing level pressure surface since the surface temperature is not known. This program requires, in addition to the FORTRAN library, the Background library, Utility library, and AFOSE library.

Machine Requirements:

This program uses less than 10K of core and runs in about 10 seconds. Thirty-one (31) blocks of storage are required on disk for the program and one data channel is used.

III. Procedures

The program is initiated and data are entered on the command line (line 25) of the AFOS ADM consoles as follows:

```
RUN: FZL  - -1- - / - -2- - / - -3- - / 4                    [12]
```

1 = Sea-level pressure (mb)

2 = 700-mb height (geopotential meters)

3 = 500-mb height (geopotential meters)

4 = {1 if significant precipitation is expected during preceding 12 hours; otherwise 4 = 0.}

After the command in (12) above is initiated, the system passes the parameters to the ICE2.CM file on DP0 where the program opens and reads in the data. Upon program completion, the results are sent back to the ADM screen via the FORKO Routine and the ALARM/ALERT button (red flashing light) is triggered. Along with the freezing level, the 850-mb, 700-mb, and 500-mb temperatures (°C) are also displayed.

Cautions and Restrictions:

Below in Table I the actual freezing level and 850-, 700-, and 500-mb temperatures for the given days are compared against the program results.

As is evident from Table I, the actual values compare very favorably with the values obtained from the program when using actual heights and sea-level pressures for the given days. The comparison was included to demonstrate the accuracy of the program.

Using interpolated actual height data and sea-level pressures can be useful when trying to determine freezing levels in between RAOB grid points or in areas of missing data. Of course, the program is also designed to be used in conjunction with the upper-air progs. Some variance from the actual data should be expected due to small errors/smoothing done by the LFM/PE progs. One should extract the heights and sea-level pressures from the progs carefully and modify them if an error in the prog is suspected.

Since the program approximates the actual sounding, using only three predicted temperatures, the freezing level determination will certainly disagree somewhat with the actual freezing level obtained from the entire sounding due to the program smoothing. These differences, however, were found to be quite small.

The input factor governing significant precipitation during the previous 12 hours, relative to the computation, is not precisely defined. This factor was included, as explained above, to modify the 850-mb - 700-mb temperatures by computing the wet-bulb temperatures. The modification of the temperatures toward the wet-bulb temperatures is most likely to occur during a sustained precipitation event, rather than during a relatively short convective event during the preceding 12 hours. Therefore, the type of precipitation is just as or more important than the quantity. It was found, if one used the LFM prog, that this usually corresponded well with the advection of the 90% RH value across the computation area.

STN	DATE 1980	ACTUAL FRZG LVL (FT)	PROG FRZG LVL (FT)	ACTUAL 500MB TEMP C	PROG 500MB TEMP C	ACTUAL 700MB TEMP C	PROG 700MB TEMP C	ACTUAL 850MB TEMP C	PROG 850MB TEMP C	SIG PCPN PAST 12 HRS
MFR	6/26	6200	6000	-26	-27	-7	-8	2	2	X
GEG	"	9900	9900	-17	-17	0	0	8	9	
BOI	"	12000	12300	-14	-13	5	7	15	15	
GGW	"	13500	13500	-13	-10	7	6	15	15	
LAS	"	15400	15300	-7	-6	12	11	22	22	
OAK	"	12100	12300	-10	-11	4	4	13	12	
SLE	6/28	12000	11800	-12	-11	4	3	12	11	
GTF	"	9200	9900	-16	-17	-2	0	10	9	
BOI	"	12700	12700	-12	-11	6	5	15	14	
SLC	"	14000	13500	-9	-10	7	7	16	16	
LAS	"	14800	14900	-10	-9	12	11	27	22	
TUS	"	14500	14700	-11	-10	13	12	26	25	
OAK	"	13600	13700	-10	-12	10	9	20	21	
UIL	"	8200	7800	-18	-18	-3	-3	4	5	
GEG	7/2	11800	11800	-14	-13	4	4	17	13	
SLC	"	13000	13500	-10	-11	6	7	17	17	
GTF	"	12000	12100	-13	-15	5	5	18	16	
LAS	"	13600	13600	-8	-10	7	7	16	16	
TUS	"	13900	14500	-7	-10	10	10	22	21	
OAK	"	11600	12000	-13	-14	3	4	13	14	
UIL	8/2	10600	10300	-10	-12	3	0	6	8	X
MSP	"	12000	11700	-11	-12	4	4	13	13	X

Table 1. Actual vs. progged freezing heights and upper level temperatures.

```
C     FREEZING LEVEL PROGRAM
C     KENNETH B. MIELKE...WSFO GREAT FALLS   JULY 1980
C
C     RLDR FZL.RB WET.RB BG.LB UTIL.LB FORT.LB AFOSE.LB
C
C     OUTPUTS FRZG LVL(MSL)..AND 500MB/700MB/850MB PREDICTED TEMPS
C
C     INPUT SEA LVL PRES(MB..4 DIGITS)..700MB AND 500MB HGTS(GPM..4 DIGITS) AND
C     RH FACTOR EQUAL TO 1 OR 0
C
C     ADM COMMAND LINE (LINE 25)
C     RUN:FZL----/----/----/-  ....SEA LVL PRES,700MB HGT,500MB HGT AND RH FACTOR RESP.
C
      REAL L
      EXTERNAL WET
      DIMENSION IAR(3),S1(14),IUP(14),IP(14)
      CALL OPEN(1,"ICE2.CM",2,IER,64)
      READ(1,10)P,H7,H5,RH
10    FORMAT(T5,F4.0,T10,F4.0,T15,F4.0,T20,F1.0)
      PS=P
      CALL DATE(IAR,IER)
C  NEXT TWO STATEMENTS CALCULATE THE AMOUNT THE SOLAR INSOLATION AFFECTING
C  850 TMP FOR THIS DATE.
       E2=(IAR(1)*30. + IAR(2)-30.)/2.
      E1=2*(SIN(((E2))/57.286))**2
C   DETERMINE THE 700/850/500MB TMPS USING THE HYPSOMETRIC EQ.
      T7=H5*(9.8/287.04)/(ALOG(P/500.))-273. -1. ;SUBTRACT 1 DEG FOR VIRTUAL TEMP COR
      T85=H7*(9.8/287.04)/(ALOG(P/700.))-273+E1-1.; SUBTRACT 1 DEG FOR VIRTUAL TMP COR
C   USE PREV COMPUTED 700MB TMP AND APPLY HYPSOMETRIC EQ AGN TO COMPUTE 500MB TMP
      VT=(H5-H7)*(9.8)/(ALOG(700./500.)*(287.04))
      AT=VT-1. ;VIRTUAL TMP COR
      T5=(2*AT-(T7+273.))-273.
      IF(RH.LT.1.) GOTO 50
C   IF RH EQ TO 1, GO TO SUBROUTINE TO COMPUTE WET BULB TMPS
C   AT 850 AND 700 MB.
      A=850.
      CALL WET(T85,A,T,P)
      T85=T
      A=700.
      CALL WET(T7,A,T,P)
      T7=T
C  LAPSE RATE 700 TO 850 MB PER MB
50    L=(T7-T85)/150.
      IF(T7.GT.0.) GOTO 20
      IF(T85.LT.0.) GOTO 25
      T=T85
      P=850.
      DO 30 I=1,150
      T=L+T
      P=P-1
      IF(T.LE.0.) GOTO 35
30    CONTINUE
      GOTO 35
C   FZG LVL ABV 700MB; USE PREV COMPUTED 700MB TMP AND APPLY HYPSOMETRIC
C   EQ AGAIN TO COMPUTE 500 MB TMP.
20    P=700
      T=T7
C   LAPSE RATE 500-700MB
      L=(T5-T7)/200.
      DO 40 I=1,200
      C=1.
C  NEXT STATEMENT CORRECTS LAPSE RATE ABV 600MB
      IF(I.GT.50) C=600./(650.-I)
      T=T+L*C
      P=P-1
      IF(T.LE.0.)GOTO 35
40      CONTINUE
```

```
      GOTO 35
C     FZG LVL BELOW 850MB; ASSUME 700-850MB LAPSE RATE XTNDS TO SFC
25    P=850
      T=T85
      DO 45 I=1,200
      T=-L+T
      P=P+1
      IF(T.GE.0.) GOTO 35
45     CONTINUE
C    AT THIS POINT FZG LVL IN MB (P0) IS KNOWN; CONVERT TO FEET MSL
35     P0=P
C     CALCULATE VT BTWN FZL AND 850
      AP=(P+850.)/2 ;AVE PRES BTN FZG LVL AND 850MB
C   CALC LAPSE RATE BTWN FZL LVL AND 850
      AL=-T85/(850.-P0)
      T1=T85
      IF(AP.GT.850.) GOTO 57
      PP=850-AP
      IPP=IFIX(PP)
      DO 55 I=1,IPP
      T1=T1+AL
55    CONTINUE
      GOTO 59
57     IAP=IFIX(AP)
      DO 58 I=850,IAP
      T1=T1+AL
58     CONTINUE
59    VT=(T1+1)+273.
      IF(P0.GT.700.) VT=VT-1.
      IF(P.GE.PS) P=PS
      FL=(ALOG(PS/P0)*VT*(287.04)/9.8)*(3.28)
      IFL=(IFIX((FL+50.)/100.))*100 ;ROUND FZG LVL TO NEAREST 100 FT
      IF(IFL.LT.0) IFL=0
      IUP(1)=106K ;F
      IUP(2)=114K ;L
      IUP(3)=40K
      IUP(4)=75K ;=
      IUP(5)=40K
      IUP(11)=40K
      IUP(12)=106K ;F
      IUP(13)=124K ;T
      IUP(6)=IFL/10000+48.
      IF(IFL.LT.10000) IUP(6)=40K
      N1=IFL/10000
      IUP(7)=(IFL-10000*N1)/1000 + 48.
      IF(IFL.LT.1000) IUP(7)=40K
      N1=IFL/1000
      IUP(8)=(IFL-1000*N1)/100 + 48.
      IF(IFL.LT.100) IUP(8)=40K
      IUP(9)=60K
      IUP(10)=60K
      X=FLOAT(IFL)
      CALL PACK(IUP,13,IP)
      CALL FORKO("FZG LEVEL ",IP(1),IER)
      IUP(1)=40K
      IUP(5)=40K
      IUP(9)=40K
      IUP(4)=57K
      IUP(8)=57K
      IF(T85.LT.0.) IUP(1)=55K
      IF(T7.LT.0.) IUP(5)=55K
      IF(T5.LT.0.) IUP(9)=55K
      T85=ABS(T85)+.5
      T7=ABS(T7)+.5
      T5=ABS(T5)+.5
      IUP(2)=T85/10 +48
      IF(T85.LT.10.) IUP(2)=60K
```

```
    IUP(3)=(T85-(IUP(2)-48)*10)+48.
    IUP(6)=T7/10 +48
    IF(T7.LT.10.) IUP(6)=60K
    IUP(7)=(T7-(IUP(6)-48)*10)+48.
    IUP(10)=T5/10+48
    IF(T5.LT.10.) IUP(10)=60K
    IUP(11)=(T5-(IUP(10)-48)*10)+48.
    CALL PACK(IUP,11,IP)
    CALL FORKO(IP(1),"850/700/500 T",IER)
    CALL CLOSE(1,IER)
    STOP
    END
```

```
C  SUBROUTINE TO COMPUTE LCL AND WET TEMPERATURE AT 700,850 MB
C    DETERMINE DWPNT TEMP...ASSUME RH=80%
      SUBROUTINE WET(TX,A,T,P)
      T1=(5420.51)*((.00366)-1/(TX+273))
      T2=T1+ALOG(.8) +1.81-21.649
      TD=-5420.51/T2-273.
C      DETERMINE TEMP AT LCL
      T=TD-(.212 +.00157*TD-.000436*TX)*(TX-TD)
C      DETERMINE PRES AT LCL
      P=A*((T+273.)/(TX+273))**3.5
C     USE MOIST ADIABTIC EQUATION TO FIND WET BULB TEMP AT ORIG
C     PRESS LEVEL.
C     ROUND PRES TO NEAREST 10 MB.
      P=FLOAT(IFIX((P/10.)+.5))*10
C      SATURATION VAPOR PRES FORMAULA
10    E=6.11*10.**((7.567*T)/(239.7+T))
C      LATENT HEAT OF CONDENSATION CALC
      Z0=2428.45+(303.-(T+273.))*(204.60)/80.
C      DETERMINE MOIST ADIABATIC LAPSE RATE...NXT 4 STEPS
      ZM1=P+(.622)*Z0*E/((.287)*(T+273))
      ZM2=P+(.622)*(E*Z0**2)/((1.003)*(.461)*(T+273)**2)
      ZM3=(.287)*(T+273)/(1.003*P)
      ZM4=ZM3*ZM1/ZM2
C     NEW T
      T=ZM4*1.0+T
C  INCREASE P BY 1 MB
      P=P+1
      IF(P.EQ.A) GOTO 60
      GOTO 10
60    RETURN
      END
```

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