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APPENDIX A

Standard Useful Constant

Gravitational constant	$G = 6.673 \times 10^{-11}$ N m^2 kg^{-2}
Acceleration due to gravity at sea level	$g_0 = 9.81$ m s^{-2}
Mean radius of the earth	$a = 6.37 \times 10^6$ m
Angular speed of rotation of the earth	$\Omega = 7.292 \times 10^{-5}$ rad s^{-1}
Universal gas constant	$R^* = 8.314 \times 10^3$ JK^{-1} kmol^{-1}
Gas constant for dry air	$R = 287$ JK^{-1} kg^{-1}
Specific heat of air at constant pressure	$c_p = 1004$ JK^{-1} kg^{-1}
Specific heat of dry air at constant volume	$c_v = 717$ JK^{-1} kg^{-1}
Ratio of specific heats	$\gamma = c_p / c_v = 1.4$
Mass of the earth	$M = 5.988 \times 10^{24}$ kg
Standard sea level pressure	$p_0 = 101.325$ kPa
Standard sea level temperature	$T_0 = 288.15$ K
Standard sea level density	$\rho_0 = 1.225$ kg m^{-3}

APPENDIX B

We will show that any vector $\vec{V}$ can be written in the form

$$\vec{V} = \vec{V}_r + \vec{V}_e \qquad \text{(B.1)}$$

where $\vec{V}_r$ is a nondivergent vector and $\vec{V}_e$ an irrotational vertor, that is,

$$\nabla \times \vec{V}_e = 0 \qquad \text{and} \qquad \nabla . \vec{V}_r = 0$$

In order to prove eq.(B.1) we define a vector $\vec{W}$ such that

$$\nabla^2 \vec{W} = - \vec{V} \qquad \text{(B.2)}$$

And using a vector identity we may write

$$- \nabla^2 \vec{W} = - \nabla(\nabla . \vec{W}) + \nabla \times \nabla \times \vec{W} \qquad \text{(B.3)}$$

We next define a scalar potential χ and a vector potential $\vec{A}$ as follows

$$\chi = \nabla . \vec{W}, \qquad \vec{A} = \nabla \times \vec{W} \qquad \text{(B.4)}$$

From (B.2)-(B.4) we find that

$$\vec{V} = \nabla\chi + \nabla \times \vec{A} \qquad \text{(B.5)}$$

But it can be shown by direct expansion into components that

$$\nabla \times \nabla\chi = 0 \qquad \text{and} \qquad \nabla . (\nabla \times \vec{A}) = 0$$

thus, $\nabla\chi = \vec{V}_e$ and $\nabla \times \vec{A} = \vec{V}_r$ which was to be proved.

If $\vec{V}$ is a two-dimensional vector, $\vec{V} = \hat{i}u + \hat{j}v$, then $\nabla \times \vec{A}$ must have its component zero. In that case $\vec{A} = \hat{k}A_z = \hat{k}\psi$ and we may write

$$\vec{V}_r = \nabla \times (\hat{k}\psi) = \hat{k} \times \nabla \psi \qquad (B.6)$$

Thus in the two-dimensional case $\vec{V}_r$ is uniquely determined by the streamfunction ψ. The complete two-dimensional velocity field can thus be written in cartesian components as

$$u = -\frac{\partial \psi}{\partial y} + \frac{\partial \chi}{\partial x}, \qquad v = \frac{\partial \psi}{\partial x} + \frac{\partial \chi}{\partial y} \qquad (B.7)$$

From which it follows that

$$\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} = \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)\psi$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)\chi$$

APPENDIX C

```
C      PROGRAM NWPI
C      ***** DATA INITIALIZATION *****
C      THIS PROGRAM CAN COMPUTE STREAMFUNCTION
C      FROM WIND VELOCITY FOR 2-LEVEL MODEL
C      WV IS THE WIND VELOCITY ( M/S)
C      WD IS THE WIND DIRECTION (DEGREE)
C      U  IS THE WIND VELOCITY IN-X DIRECTION (M/S)
C      V  IS THE WIND VELOCITY IN-Y DIRECTION (M/S)
C      A  IS THE FORCING FUNCTION
C
       PARAMETER(L=38,M=19,N=2,LC=40)
       DIMENSION U(L,M,N),V(L,M,N),PSI(L,M,N),PSIC(LC,M,N),
     *           A(L,M,N),WV(L,M,N),WD(L,M,N)
       COMMON DX(M),DY,PHI(M),COR(M),DPSI(L,M)
       PI=3.1415927
       RAD=PI/180.
       LC1=LC-1
       L1=L-1
       M1=M-1
       M2=M-2
       CALL CONST(DX,DY,PHI,COR,L,M,N)
       CALL INPUTV(WV,WD,HA,HB,L,M,N)
       PRINT*,' '
C
       DO 11 K=1,N
       DO 11 J=1,M
       DO 11 I=1,L
          U(I,J,K)=(-1.)*WV(I,J,K)*SIN(WD(I,J,K)*RAD)
          V(I,J,K)=(-1.)*WV(I,J,K)*COS(WD(I,J,K)*RAD)
    11 CONTINUE
       DO 35 K=1,N
       DO 35 J=2,M1
          DO 34 I=2,L1
             A(I,J,K)=(V(I+1,J,K)-V(I-1,J,K))/(2.*DX(J))
     *                -(U(I,J+1,K)-U(I,J-1,K))/(2.*DY)
    34    CONTINUE
          A(1,J,K)=(V(2,J,K)-V(L1,J,K))/(2.*DX(J))
     *             -(U(1,J+1,K)-U(1,J-1,K))/(2.*DY)
          A(L,J,K)=A(1,J,K)
    35 CONTINUE
       DO 36 K=1,N
       DO 36 I=1,L
          A(I,1,K)=2.*A(I,2,K)-A(I,3,K)
          A(I,M,K)=2.*A(I,M1,K)-A(I,M2,K)
    36 CONTINUE
C
       PRINT*,' '
       PRINT*,'       ***********************************************'
       PRINT*,'                            TWO-LEVEL'
       PRINT*,'       -----------------------------------------------'
       WRITE(6,798)
   798 FORMAT(8X,'         UNO         VNO          EPS     ')
```

```
C
      VNO=0.0
      UNO=0.0
C
C    .................
      DO 999 K=1,N
C    ----------------
C
      VNO=V(1,M,K)*DX(M)/2.+V(L,M,K)*DX(M)/2.+VNO
      UNO=ABS(V(1,M,K))*DX(M)/2.+ABS(V(L,M,K))*DX(M)/2.+UNO
      DO 2006 I=2,L1
         UNO=UNO+ABS(V(I,M,K))*DX(M)
         VNO=VNO+V(I,M,K)*DX(M)
 2006 CONTINUE
      VNO=VNO+U(L,M,K)*DY/2.+U(L,1,K)*DY/2.
      UNO=UNO+ABS(U(L,M,K))*DY/2.+ABS(U(L,1,K))*DY/2.
      DO 2007 J=2,M1
         UNO=UNO+ABS(U(L,J,K))*DY
         VNO=VNO+U(L,J,K)*DY
 2007 CONTINUE
      VNO=VNO-V(L,1,K)*DX(1)/2.+V(1,1,K)*DX(1)/2.
      UNO=UNO+ABS(V(L,1,K))*DX(1)/2.+ABS(V(1,1,K))*DX(1)/2.
      DO 2008 I=2,L1
         UNO=UNO+ABS(V(I,1,K))*DX(1)
         VNO=VNO-V(I,1,K)*DX(1)
 2008 CONTINUE
      VNO=VNO-U(1,1,K)*DY/2.+U(1,M,K)*DY/2.
      UNO=UNO+ABS(U(1,1,K))*DY/2.+ABS(U(1,M,K))*DY/2.
      DO 2009 J=2,M1
         UNO=UNO+ABS(U(1,J,K))*DY
         VNO=VNO-U(1,J,K)*DY
 2009 CONTINUE
  999 CONTINUE
C     +++++++++++++++++++++++++++++++++++++
      EPS=(VNO/UNO)*(-1.0)
C
C     CORRECTION TO THE OUTWARD NORMAL VELOCITY
C     IS PROPORTIONAL TO ITS MAGNITUDE
C
  799 FORMAT(10X,3E12.3)
      WRITE(6,799) UNO,VNO,EPS
      PRINT*,' '
      PRINT*,'       ---------------------------------------------'
C     ++++++++++++++++++++++++++++++
      DO 111 K=1,N
         DO 2010 I=1,L
            V(I,1,K)=V(I,1,K)+EPS*ABS(V(I,1,K))
            V(I,M,K)=V(I,M,K)-EPS*ABS(V(I,M,K))
 2010    CONTINUE
         DO 2011 J=1,M
            U(1,J,K)=U(1,J,K)+EPS*ABS(U(1,J,K))
            U(L,J,K)=U(L,J,K)-EPS*ABS(U(L,J,K))
 2011    CONTINUE
```

```
  111 CONTINUE
C
C      ++++++++++++++++++++++++++++++
C
C      ASSUME POINT (1,M,K) IS KNOWN. THE REMAINING
C      BOUNDARY VALUES ARE COMPUTED USING THE CORRECTED
C      OUTWARD NORMAL VELOCITY.
C
       DO 222 K=1,N
         PSI(1,M,K)=0.0
         DO 2012 I=2,L
           PSI(I,M,K)=PSI(I-1,M,K)+(V(I,M,K)+V(I-1,M,K))*DX(M)/2.
 2012    CONTINUE
         DO 2013 JJ=1,M1
           J=M-JJ
           PSI(L,J,K)=PSI(L,J+1,K)+(U(L,J,K)+U(L,J+1,K))*DY/2.
 2013    CONTINUE
         DO 2014 II=1,L1
           I=L-II
           PSI(I,1,K)=PSI(I+1,1,K)-(V(I,1,K)+V(I+1,1,K))*DX(1)/2.
 2014    CONTINUE
         DO 2015 J=2,M1
           PSI(1,J,K)=PSI(1,J-1,K)-(U(1,J,K)+U(1,J-1,K))*DY/2.
 2015    CONTINUE
  222 CONTINUE
C      ++++++++++++++++++++++++++++++++++++
C
C      CALL RELAXT TO SOLVE THE POISSON EQUATION
C      VIA THE OVERRELAXATION METHOD.
C
       PRINT*,' '
       PRINT*,'                        PROGRAM IS OPERATING'
       PRINT*,'                        ************************      '
       PRINT*,' '
       CALL RELAXT(PSI,A,DX,DY,L,M,N)
C
C      INTERPOLATE PSI AT LEVEL 250 MB AND 750 MB
C
       DO 333 J=1,M
       DO 333 I=1,L
          DPSI(I,J)=PSI(I,J,2)-PSI(I,J,1)
  333 CONTINUE
C
       DO 444 J=1,M
       DO 444 I=1,L
          PSI(I,J,2)=(550.0/650.0)*DPSI(I,J)+PSI(I,J,1)
          PSI(I,J,1)=(50.0/650.0)*DPSI(I,J)+PSI(I,J,1)
  444 CONTINUE
C
C      INTERPOLATE FINISH
C
       CALL EQUAL(PSI,PSIC,L,LC,M,N)
       CALL CYCLE(PSI,PSIC,L,LC,M,N)
```

```
      PRINT*,' '
      CALL OUT(PSIC,LC,M,N)
      PRINT*,' '
      PRINT*,'!PROGRAM CALCULATING INITIAL STREAMFUNCTION HAS FINISHED'
      PRINT*,'* IF YOU WANT TO FORCAST THE WEATHER ??? '
      PRINT*,' '
      PRINT*,'********  PRINT  NWPF *********'
      STOP
      END
C
C     ******************
      SUBROUTINE CONST
C     ******************
C
      PARAMETER (L=38,M=19,N=2)
      COMMON DX(M),DY,PHI(M),COR(M)
      DPHI=2.5
      SLAT=0.0
      PI=3.1415927
      RAD=PI/180.
      DY=DPHI*RAD*6.37*1000000.
      PHI(1)=SLAT
      DO 10 J=2,M
         PHI(J)=PHI(J-1)+DPHI
   10 CONTINUE
      DO 20 J=1,M
         DX(J)=DY*COS(PHI(J)*RAD)
         COR(J)=2.*7.292E-5*SIN(PHI(J)*RAD)
   20 CONTINUE
      RETURN
      END
C
C     ********************************
      SUBROUTINE EQUAL(A,B,L,LC,M,N)
C     ********************************
C
      DIMENSION A(L,M,N),B(LC,M,N)
      DO 100 K=1,N
      DO 100 J=1,M
      DO 100 I=1,L
         B(I,J,K)=A(I,J,K)
  100 CONTINUE
      RETURN
      END
C
C     *********************************
      SUBROUTINE CYCLE(Z,PC,L,LC,M,N)
C     *********************************
C
      DIMENSION Z(L,M,N),PC(LC,M,N)
      DO 15 K=1,N
         DO 20 J=1,M
            PC(LC,J,K)=Z(1,J,K)
```

```
          PC(LC-1,J,K)=(Z(L,J,K)+Z(1,J,K))/2.0
   20     CONTINUE
   15 CONTINUE
      RETURN
      END
C
C    .................................
      SUBROUTINE RELAXT(X,Y,DX,DY,L,M,N)
C    .................................
C
      DIMENSION X(L,M,N),Y(L,M,N),DX(M)
      ERR=2.0
      ALFA=0.33
      NPTS=(L-2)*(M-2)
      L1=L-1
      M1=M-1
      IA=1000
      DO 100 K=1,N
        NSC=0
        LSC=-1
   15   NREL=0
        DO 2 J=2,M1
        DO 2 I=2,L1
          IM1=I-1
          IP1=I+1
          IF(IM1.LT.1) IM1=L1
          IF(IP1.GT.L) IP1=2
          R=(X(IP1,J,K)+X(IM1,J,K)-2.*X(I,J,K))/DX(J)**2+(X(I,J+1,K)
     *      +X(I,J-1,K)-2.*X(I,J,K))/DY**2
          R=(R-Y(I,J,K))*DY*DX(J)
          IF(LSC-NSC) 29,29,30
   29     X(I,J,K)=X(I,J,K)+ALFA*R
   30     IF(ABS(R).LE.ERR) NREL=NREL+1
    2   CONTINUE
        NSC=NSC+1
        IF(NREL-NPTS) 13,14,14
   14   IF(LSC.GE.NSC) GO TO 300
   18   LSC=LSC+1
   13   IF(NSC.LT.IA) GO TO 15
        PRINT*,'      ------------------------------------------------'
  201   FORMAT(8X,'PROGRESS OF RELAXATION NPTS,NREL,NSC,IA,LEVEL')
  300   CONTINUE
        PRINT*,' '
        WRITE(6,201)
  200   FORMAT(5X,5I9)
        WRITE(6,200)NPTS,NREL,NSC,IA,K
        PRINT*,' '
  100 CONTINUE
      PRINT*,'      ------------------------------------------------'
      RETURN
      END
C
C    .................................
```

```
      SUBROUTINE INPUTV(WV,WD,HA,HB,L,M,N)
C     ........................................
C
      DIMENSION WV(L,M,N),WD(L,M,N),HA(N),HB(N)
      CHARACTER F*10
      PRINT*,' INPUT FILENAME OF WIND VELOCITY (''____.___'')'
      READ*,F
      OPEN(UNIT=13,FILE=F,ACCESS='SEQUENTIAL',STATUS='OLD')
      DO 20 KK=1,N
        K=3-KK
        READ(13,FMT=11)HA(K)
        DO 30 J=1,M
          READ(13,FMT=10)(WD(I,J,K),I=20,L)
          READ(13,FMT=10)(WV(I,J,K),I=20,L)
   30   CONTINUE
        READ(13,FMT=11)HB(K)
        DO 3 J=1,M
          READ(13,FMT=10)(WD(I,J,K),I=1,19)
          READ(13,FMT=10)(WV(I,J,K),I=1,19)
   3    CONTINUE
   20 CONTINUE
   10 FORMAT(19F7.1)
   11 FORMAT(A60)
      CLOSE(UNIT=13,STATUS='KEEP')
      PRINT*,' '
      PRINT*,F,'HAS BEEN READ ALREADY '
      RETURN
      END
C
C     ..............................
      SUBROUTINE OUT(PSIC,LC,M,N)
C     ..............................
C
      DIMENSION PSIC(LC,M,N)
      CHARACTER*10 F
      PRINT*,' STREAMLINE FILENAME (''____.___'')'
      READ*,F
      OPEN(UNIT=13,FILE=F,ACCESS='SEQUENTIAL',STATUS='NEW')
      DO 30 K=1,N
      DO 30 J=1,M
         WRITE(UNIT=13,FMT=10)(PSIC(I,J,K),I=1,20)
         WRITE(UNIT=13,FMT=10)(PSIC(I,J,K),I=21,LC)
         WRITE(6,10)(PSIC(I,J,K),I=1,20)
         WRITE(6,10)(PSIC(I,J,K),I=21,LC)
   30 CONTINUE
   10 FORMAT(20E9.2)
      CLOSE(UNIT=13,STATUS='KEEP')
      RETURN
      END
```

APPENDIX D

```
C    PROGRAM  NWPF
C
C    ''NUMERICAL WEATHER FORECASTING''
C    ''''''''  TWO-LEVEL MODEL ''''''''
C
C    FOLLOWING IS A LIST OF ESSENTIAL DATA FOR THE PROGRAM.
C    L IS THE NUMBER OF GRID-POINTS IN THE ZONAL DIRECTION.
C    M IS THE NUMBER OF GRID-POINTS IN THE MERIDIONAL DIRECTION.
C    N IS THE NUMBER OF LEVELS
C    TEND IS THE NUMBER OF HOURS FOR THE FORECAST.
C
      PARAMETER (L=40,M=19,N=2,LAMDA=0.0672E-5)
      DIMENSION A2(L,M,N),A4(L,M,N)
      DIMENSION B1(L,M,N),B2(L,M,N)
      DIMENSION C1(L,M,N),C2(L,M,N),AK(N)
      COMMON  PHI(M),DY,DX(M),COR(M),PSII(L,M,N),
     *         PSI(L,M,N),A1(L,M,N),A3(L,M,N)
      EQUIVALENCE (A1,A2)
      REAL TEND,DT,TIME
      M1=M-1
      L1=L-1
      DT=1800.0
      PRINT*,' '
      PRINT*,' ' THE NUMBER OF HOURS FOR THE FORECAST:(HOURS) ''
      READ*, TEND
      CALL INPUT(PSI,L,M,N)
      PRINT*,' '
C
C     INITIAL STATE PARAMETERS, PSI
C     AND PSII ARE DEFINED BY SUBROUTINE "INIT".
C
      TIME=0.0
      TEND=TEND*3600.
      CALL INIT
      PRINT*,' '
      PRINT*,'   ............................................... '
      PRINT*,' '
      CALL LAP(A3,PSII,DX,DY,L,M,N,1)
      CALL LAP(A3,PSII,DX,DY,L,M,N,2)
      CALL JCC(B2,PSII,L,M,N,DX,DY)
      DO 90 J=1,M
      DO 90 I=1,L
         A3(I,J,2)=A3(I,J,2)-2.*(LAMDA**2)*PSII(I,J,2)
   90 CONTINUE
C
C     @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
C
  555 CONTINUE
C
      CALL ENERGY(PSI,L,M,N,DX,DY,TIME,AK,TEND)
```

```
C
      CALL LAP(A1,PSI,DX,DY,L,M,N,1)
      CALL ABVOR(A1,COR,L,M,N,1)
      CALL JAC(B1,PSI,A1,DX,DY,L,M,N,1)
C
      CALL LAP(A1,PSI,DX,DY,L,M,N,2)
      CALL ABVOR(A1,COR,L,M,N,2)
      CALL JAC(B1,PSI,A1,DX,DY,L,M,N,2)
C
      DO 12 J=1,M
      DO 12 I=1,L
         C1(I,J,1)=-B1(I,J,1)-B1(I,J,2)
         C1(I,J,2)=-B1(I,J,1)+B1(I,J,2)+(LAMDA**2)*B2(I,J,1)
   12 CONTINUE
C
C  HERE TIME INTEGATION ARE CALCULATE BY MATSUNO SCHEME
C
      DO 100 K=1,N
      DO 100 J=1,M
      DO 100 I=1,L
         A4(I,J,K)=A3(I,J,K)+C1(I,J,K)*DT
  100 CONTINUE
C
C  HERE A4 IS RELAXED TO GIVE A NEW PSII.
C
      CALL RELAXT(PSII,A4,DX,DY,L,M,N,LAMDA,1)
      CALL RELAXT(PSII,A4,DX,DY,L,M,N,LAMDA,2)
C
      CALL JCC(B2,PSII,L,M,N,DX,DY)
C
      DO 112 J=2,M1
      DO 112 I=1,L
         PSI(I,J,1)=(PSII(I,J,1)+PSII(I,J,2))/2.
         PSI(I,J,2)=(PSII(I,J,1)-PSII(I,J,2))/2.
  112 CONTINUE
C
      CALL LAP(A2,PSI,DX,DY,L,M,N,1)
      CALL ABVOR(A2,COR,L,M,N,1)
      CALL JAC(B1,PSI,A2,DX,DY,L,M,N,1)
C
      CALL LAP(A2,PSI,DX,DY,L,M,N,2)
      CALL ABVOR(A2,COR,L,M,N,2)
      CALL JAC(B1,PSI,A2,DX,DY,L,M,N,2)
C
      DO 126 J=1,M
      DO 126 I=1,L
         C1(I,J,1)=-B1(I,J,1)-B1(I,J,2)
         C1(I,J,2)=-B1(I,J,1)+B1(I,J,2)+(LAMDA**2)*B2(I,J,1)
  126 CONTINUE
      DO 127 K=1,N
      DO 127 J=1,M
      DO 127 I=1,L
         A4(I,J,K)=A3(I,J,K)+C1(I,J,K)*DT
```

```
  127 CONTINUE
C
      CALL RELAXT(PSII,A4,DX,DY,L,M,N,LAMDA,1)
      CALL RELAXT(PSII,A4,DX,DY,L,M,N,LAMDA,2)
      CALL JCC(B2,PSII,L,M,N,DX,DY)
C
      DO 130 J=2,M1
      DO 130 I=1,L
         PSI(I,J,1)=(PSII(I,J,1)+PSII(I,J,2))/2.
         PSI(I,J,2)=(PSII(I,J,1)-PSII(I,J,2))/2.
  130 CONTINUE
C
      CALL CYCLE(PSI,L,M,N)
      CALL EQUAL(A3,A4,L,M,N,1)
      CALL EQUAL(A3,A4,L,M,N,2)
C
      TIME=TIME+DT
      PRINT*,'    ---------------------------------------------- '
      IF(TIME.LE.TEND) GO TO 555
C
C     @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
C
      TIME=(TIME-DT)/3600.
      PRINT*,' '
      WRITE(6,3)TIME
    3 FORMAT(2X,'FORECASTING FOR TIME =',F6.2,' HOURS HAS FINISHED')
      PRINT*,'  '
C
      CALL OUT(PSI,L,M,N)
      PRINT*,' '
      PRINT*,' '
      PRINT*,'  ??? IF YOU WANT TO PLOT WIND FIELD PRINT ***'
      PRINT*,' '
      PRINT*,'  PLOT '
      STOP
      END
C
C    ********************************
      SUBROUTINE ABVOR(A,COR,L,M,N,K)
C    ********************************
C
      DIMENSION A(L,M,N),COR(M)
      DO 100 J=2,M-1
      DO 100 I=2,L-1
           A(I,J,K)=A(I,J,K)+COR(J)
  100 CONTINUE
      DO 200 J=1,M
           A(1,J,K)=0.0
           A(L,J,K)=0.0
  200 CONTINUE
      DO 300 I=1,L
           A(I,1,K)=0.0
           A(I,M,K)=0.0
```

```
  300 CONTINUE
      RETURN
      END
C
C     ..........................
      SUBROUTINE CYCLE(Z,L,M,N)
C     ..........................
C
      DIMENSION Z(L,M,N)
      DO 15 K=1,N
      DO 15 J=1,M
          Z(L,J,K)=Z(1,J,K)
   15 CONTINUE
      RETURN
      END
C
C     ..................................
      SUBROUTINE JCC(B2,P,L,M,N,DX,DY)
C     ..................................
C
      DIMENSION B2(L,M,N),P(L,M,N),DX(M)
      L1=L-1
      M1=M-1
      DO 100 J=2,M1
          DO 90 I=2,L1
            B2(I,J,1)=((P(I,J+1,2)-P(I,J-1,2))/(2.*DY))*
     1                 (P(I+1,J,1)-P(I-1,J,1))/(2.*DX(J))-
     2                 ((P(I,J+1,1)-P(I,J-1,1))/(2.*DY))*
     3                 (P(I+1,J,2)-P(I-1,J,2))/(2.*DX(J))
   90     CONTINUE
          B2(1,J,1)=((P(1,J+1,2)-P(1,J-1,2))/(2.*DY))*
     1              (P(2,J,1)-P(L1,J,1))/(2.*DX(J))-
     2              ((P(1,J+1,1)-P(1,J-1,1))/(2.*DY))*
     3              (P(2,J,2)-P(L1,J,2))/(2.*DX(J))
          B2(L,J,1)= B2(1,J,1)
  100 CONTINUE
      CALL BOUND(B2,L,M,N,1)
      RETURN
      END
C
C     ..............................................
      SUBROUTINE ENERGY(PSI,L,M,N,DX,DY,TIME,AK,TEND)
C     ..............................................
C
      DIMENSION PSI(L,M,N),DX(M),AK(N)
      L1=L-1
      M1=M-1
      AK(1)=0.0
      AK(2)=0.0
      DO 60 K=1,N
      DO 60 J=2,M1
      DO 60 I=1,L1
      IM1=I-1
```

```
      IF (I.EQ.1) IM1=L1
      U = -(PSI(I,J+1,K)-PSI(I,J-1,K))/(2.*DY)
      V = (PSI(I+1,J,K)-PSI(IM1,J,K))/(2.*DX(J))
      AK(K) = AK(K)+(U**2+V**2)/(2*(L1)*(M1-1))
   60 CONTINUE
      TOTAL=(AK(1)+AK(2))/2.0
      PRINT*,'                   TWO-LEVEL MODEL '
      PRINT*,'                   --------------- '
      TER=TEND/3600.0
      WRITE(6,129) TER
      T1=TIME/3600.0
      WRITE(6,130) TIME,T1
      WRITE(6,131) AK(1)
      WRITE(6,132) AK(2)
      WRITE(6,133) TOTAL
  129 FORMAT(3X,'   FORECAST WEATHER FOR ',F6.2,'    HOUR(S) ')
  130 FORMAT(3X,'   TIME (DOING) =',F11.1,'  SEC(',F6.2,' HR(S))')
  131 FORMAT(3X,'   K.E(1)/POINT =',E11.3,'  AT LEVEL 250  mb')
  132 FORMAT(3X,'   K.E(2)/POINT =',E11.3,'  AT LEVEL 750  mb')
  133 FORMAT(3X,'   K.E(AVERAGE) =',E11.3)
      PRINT*,' '
      WRITE(6,201)
  201 FORMAT(1X,'        PROGRESS OF RELAXATION NPTS,NREL,NSC,IA')
      RETURN
      END
C
C     *************************************
      SUBROUTINE JAC(A,B,C,DX,DY,L,M,N,K)
C     *************************************
C
      DIMENSION A(L,M,N),B(L,M,N),DX(M),C(L,M,N)
      M1=M-1
      DO 99 J=2,M1
      DM = 12.*DX(J)*DY
      DO 99 I=1,L
      IF (I-1) 80,80,81
   80 IM1=L1
      IP1=2
      GO TO 83
   81 IF (I-L) 82,80,80
   82 IM1=I-1
      IP1=I+1
   83 CONTINUE
      A(I,J,K)=(B(I,J-1,K)+B(IP1,J-1,K)-B(I,J+1,K)-B(IP1,J+1,K))*
     1(C(IP1,J,K)-C(I,J,K))+(B(IM1,J-1,K)+B(I,J-1,K)-B(IM1,J+1,K)-
     2B(I,J+1,K))*(C(I,J,K)-C(IM1,J,K))+(B(IP1,J,K)+B(IP1,J+1,K)
     3-B(IM1,J,K)-B(IM1,J+1,K))*(C(I,J+1,K)-C(I,J,K))+
     4(B(IP1,J-1,K)+B(IP1,J,K)-B(IM1,J-1,K)-B(IM1,J,K))*
     5(C(I,J,K)-C(I,J-1,K))+
     6(B(IP1,J,K)-B(I,J+1,K))*(C(IP1,J+1,K)-C(I,J,K))+
     7(B(I,J-1,K)-B(IM1,J,K))*(C(I,J,K)-C(IM1,J-1,K))+
     8(B(I,J+1,K)-B(IM1,J,K))*(C(IM1,J+1,K)-C(I,J,K))+
     9(B(IP1,J,K)-B(I,J-1,K))*(C(I,J,K)-C(IP1,J-1,K))
```

```
      A(I,J,K)=A(I,J,K)/DM
   99 CONTINUE
      DO 700 I=1,L
      IF (I-1) 70,70,71
   70 IM1=L1
      IP1=2
      GO TO 73
   71 IF (I-L) 72,70,70
   72 IM1=I-1
      IP1=I+1
   73 CONTINUE
      A(I,1,K)=(B(I,1,K)+B(IP1,1,K)-B(I,2,K)-B(IP1,2,K))*
     1(C(I,1,K)+C(IP1,1,K))-(B(IM1,1,K)+B(I,1,K)-
     2B(IM1,2,K)-B(I,2,K))*(C(IM1,1,K)+C(I,1,K))+
     3(B(IP1,1,K)+B(IP1,2,K)-B(IM1,1,K)-B(IM1,2,K))*(C(I,1,K)+
     4C(I,2,K))+(B(IP1,1,K)-B(I,2,K))*
     5(C(I,1,K)+C(IP1,2,K))+(B(I,2,K)-
     6B(IM1,1,K))*(C(IM1,2,K)+C(I,1,K))
      DM=12.*DX(1)*DY
      A(I,1,K)=A(I,1,K)/DM
      A(I,M,K)=(B(I,M-1,K)+B(IP1,M-1,K)-B(I,M,K)-
     2B(IP1,M,K))*(C(I,M,K)+C(IP1,M,K))-
     3(B(IM1,M-1,K)+B(I,M-1,K)-B(IM1,M,K)-
     4B(I,M,K))*(C(IM1,M,K)+C(I,M,K))-
     5(B(IP1,M-1,K)+B(IP1,M,K)-B(IM1,M-1,K)-
     6B(IM1,M,K))*(C(I,M-1,K)+C(I,M,K))-
     7(B(I,M-1,K)-B(IM1,M,K))*(C(IM1,M-1,K)+
     8C(I,M,K))-(B(IP1,M,K)-B(I,M-1,K))*(C(I,M,K)+C(IP1,M-1,K))
      DM=12.*DX(M)*DY
      A(I,M,K)=A(I,M,K)/DM
  700 CONTINUE
      RETURN
      END
C
C     ...............................
      SUBROUTINE EQUAL(A,B,L,M,N,K)
C     ...............................
C
      DIMENSION A(L,M,N),B(L,M,N)
      DO 100 J=1,M
      DO 100 I=1,L
         A(I,J,K)=B(I,J,K)
  100 CONTINUE
      RETURN
      END
C
C     .................
      SUBROUTINE INIT
C     .................
C
      PARAMETER (L=40,M=19,N=2)
      COMMON PHI(M),DY,DX(M),COR(M),PSI1(L,M,N),
     *       PSI(L,M,N),A1(L,M,N),A3(L,M,N)
```

```
C
      DPHI=2.5
      SLAT=0.0
      PI=3.1415927
      RAD=PI/180.
      A=6.37'1000000.
      DY=DPHI'RAD'A
      OME=7.292E-5
      PHI(1)=SLAT
      DO 102 J=2,M
         PHI(J)=PHI(J-1)+DPHI
  102 CONTINUE
      DO 370 J=1,M
         DX(J)=DY'COS(PHI(J)'RAD)
        COR(J)=2.'OME'SIN(PHI(J)'RAD)
  370 CONTINUE
      DO 33 J=1,M
      DO 33 I=1,L
         PSII(I,J,1)=PSI(I,J,1)+PSI(I,J,2)
         PSII(I,J,2)=PSI(I,J,1)-PSI(I,J,2)
   33 CONTINUE
      RETURN
      END
C
C     ''''''''''''''''''''''''''''''''''''
      SUBROUTINE BOUND(A,L,M,N,K)
C     ''''''''''''''''''''''''''''''''''''
C
      DIMENSION A(L,M,N)
      DO 15 I=1,L
         A(I,1,K)=2.'A(I,2,K)-A(I,3,K)
         A(I,M,K)=2.'A(I,M-1,K)-A(I,M-2,K)
   15 CONTINUE
      RETURN
      END
C
C     ''''''''''''''''''''''''''''''''''''''''''''
      SUBROUTINE LAP(A,B,DX,DY,L,M,N,K)
C     ''''''''''''''''''''''''''''''''''''''''''''
C
      DIMENSION A(L,M,N),B(L,M,N),DX(M)
      L1=L-1
      M1=M-1
      DO 90 J=2,M1
      DO 90 I=2,L1
         A(I,J,K)=(B(I+1,J,K)+B(I-1,J,K)
     2            -2.'B(I,J,K))/DX(J)''2+(B(I,J+1,K)+
     3            B(I,J-1,K)-2.'B(I,J,K))/DY''2
   90 CONTINUE
      DO 91 J=2,M1
         A(1,J,K)=(B(2,J,K)+B(L1,J,K)
     2            -2.'B(1,J,K))/DX(J)''2+(B(1,J+1,K)+
     3            B(1,J-1,K)-2.'B(1,J,K))/DY''2
```

```
      A(L,J,K)=A(1,J,K)
   91 CONTINUE
      CALL BOUND(A,L,M,N,K)
      RETURN
      END
C
C     ........................................
      SUBROUTINE RELAXT(X,Y,DX,DY,L,M,N,LAMDA,K)
C     ........................................
C
      DIMENSION X(L,M,N),Y(L,M,N),DX(M)
      ERR=1000.
      ALFA=0.40
      L1=L-1
      M1=M-1
      M2=M-2
      NSC=0
      IA=500
      LSC=-1
   91 NPTS=(L1)*(M2)
   15 NREL=0
      DO 2 J=2,M1
      DO 2 I=1,L1
      IF (I-L) 3,4,4
    3 IF (I-1) 4,4,5
    4 R=(X(2,J,K)+X(L1,J,K)-2.*X(I,J,K))/DX(J)**2+(X(I,J+1,K)+
     1  X(I,J-1,K)-2.*X(I,J,K))/DY**2-2.*(LAMDA**2)*X(I,J,K)*(K-1)
      R=(R-Y(I,J,K))*DY*DX(J)
      GO TO 21
    5 R=(X(I+1,J,K)+X(I-1,J,K)-2.*X(I,J,K))/DX(J)**2+(X(I,J+1,K)+
     1  X(I,J-1,K)-2.*X(I,J,K))/DY**2-2.*(LAMDA**2)*X(I,J,K)*(K-1)
      R=(R-Y(I,J,K))*DY*DX(J)
   21 IF (LSC-NSC) 29,29,30
   29 X(I,J,K)=X(I,J,K)+ALFA*R
   30 IF (ABS(R).LE.ERR) NREL=NREL+1
    2 CONTINUE
      NSC=NSC+1
      IF (NREL-NPTS) 13,14,14
   14 IF (LSC.GE.NSC) GO TO 300
   18 LSC=NSC+1
   13 IF (NSC.LT.IA) GO TO 15
  300 CONTINUE
  200 FORMAT(6X,4I9)
      WRITE(6,200)NPTS,NREL,NSC,IA
      RETURN
      END
C
C     ............................
      SUBROUTINE INPUT(PSI,L,M,N)
C     ............................
C
      DIMENSION PSI(L,M,N)
      CHARACTER*10 F
```

```
      PRINT*,' INPUT FILENAME:''______.___''. '
      READ*,F
      OPEN(UNIT=13,FILE=F,ACCESS='SEQUENTIAL',STATUS='OLD')
      DO 20 K=1,N
      DO 30 J=1,M
         READ(13,FMT=10)(PSI(I,J,K),I=1,20)
         READ(13,FMT=10)(PSI(I,J,K),I=21,L)
   30 CONTINUE
   20 CONTINUE
   10 FORMAT(20E9.2)
      CLOSE(UNIT=13,STATUS='KEEP')
      PRINT*,' '
      PRINT*,'INPUT FILE: ',F,' HAS BEEN READ ALREADY !!!'
      PRINT*,' '
      RETURN
      END
C
C     ...........................
      SUBROUTINE OUT(PSI,L,M,N)
C     ...........................
C
      DIMENSION PSI(L,M,N)
      CHARACTER*10 FNAME
      PRINT*,' OUTPUT FILE NAME:''______.___''. '
      READ*,FNAME
      OPEN(UNIT=13,FILE=FNAME,ACCESS='SEQUENTIAL',STATUS='NEW')
      DO 20 K=1,N
      DO 30 J=1,M
         WRITE(UNIT=13,FMT=10)(PSI(I,J,K),I=1,20)
         WRITE(UNIT=13,FMT=10)(PSI(I,J,K),I=21,L)
   30 CONTINUE
   20 CONTINUE
   10 FORMAT(20E9.2)
      CLOSE(UNIT=13,STATUS='KEEP')
      PRINT*,' '
      PRINT*,' OUTPUT FILE:',FNAME,'HAS BEEN CREATED ALREADY !!!'
      RETURN
      END
```

CURRICULUM VITAE

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