--- Apr.16, 2012 ---

Manual for subroutines DC3D0 and DC3D
to calculate displacement, strain and tilt at depth due to a point/rectangular strike/dip/tensile source in a half-space

Reference

Okada, Y., 1992, Internal deformation due to shear and tensile faults in a half-space,
Bull. Seism. Soc. Am., 82, 1018-1040.

DC3D0 : Internal deformation due to a point source

---

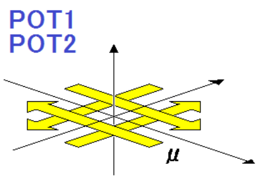
(1) Calling sequence

```
CALL DC3D0 (ALPHA, X, Y, Z, DEPTH, DIP, POT1, POT2, POT3, POT4,
            UX, UY, UZ, UXX, UYX, UZX, UXY, UYY, UZY, UXZ, UYZ, UZZ, IRET)
```

Input arguments (REAL*4)

ALPHA : Medium constant, ($\lambda + \mu$) / ($\lambda + 2\mu$) = 1 - (Vs/Vp)**2 , [Vp, Vs = P-, S-velocity]
X, Y, Z : Coordinate of observation point (Z should be Z<=0)
DEPTH : Depth of point source (DEPTH>=0)
DIP : Dip-angle of the source (degree)

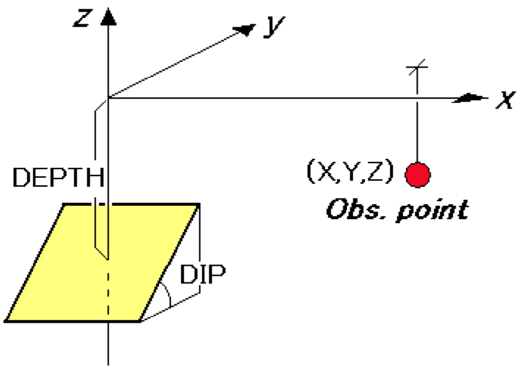
POT1 : Potency for strike-slip fault = (moment of double-couple) / μ = LWU
POT2 : Potency for dip-slip fault = (moment of double-couple) / μ =LWU
POT3 : Potency for tensile fault = (moment of isotropic part of dipole) / λ
POT4 : Potency for explosive source = (moment of dipole) / μ

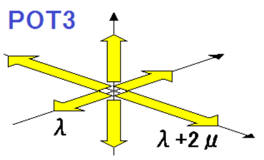


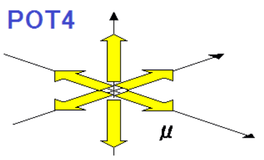
Output arguments (REAL*4)

UX, UY, UZ : Displacement
UXX,UYX, UZX : X-derivative
UXY, UYY, UZY : Y-derivative
UXZ, UYZ, UZZ : Z-derivative

IRET : Return code
: =0...normal
: =1...singular point
: =2...positive Z was given







(IRET=1 occurs when the observation point coincides to the source position)

(2) Unit of output

Unit for UX,UY,UZ = (Unit of potency) / (Unit of X,Y,Z,DEPTH)**2
Unit for UXX..UZZ = (Unit of potency) / (Unit of X,Y,Z,DEPTH)**3

So, if potency is given in unit of cm**3 and X, Y, Z, DEPTH are given in unit of km, UX, UY, UZ (in cm) can be obtained by multiplication of 10**(-10) to the output, while UXX, UYX,..., UZZ in correct unit can be obtained by multiplication of 10**(-15).

(3) Subroutines called by DC3D0 : DCCON0, DCCON1, UA0, UB0, UC0

DC3D : Internal deformation due to a rectangular fault source

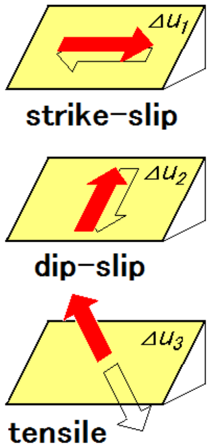
(1) Calling sequence

CALL DC3D (ALPHA, X,Y,Z, DEPTH, DIP, AL1,AL2, AW1,AW2, DISL1,DISL2,DISL3,
UX, UY, UZ, UXX, UYX, UZX, UXY, UYY, UZY, UXZ, UYZ, UZZ, IRET)

Input arguments (REAL*4)

ALPHA : Medium constant, $(\lambda+\mu)/(\lambda+2\mu) = 1 - (Vs/Vp)^{**}2$, [Vp, Vs = P-, S-velocity]
X, Y, Z : Coordinate of observation point (Z should be Z<=0)
DEPTH : Depth of reference point on the fault surface (DEPTH>=0)
DIP : Dip-angle of the fault surface (degree)

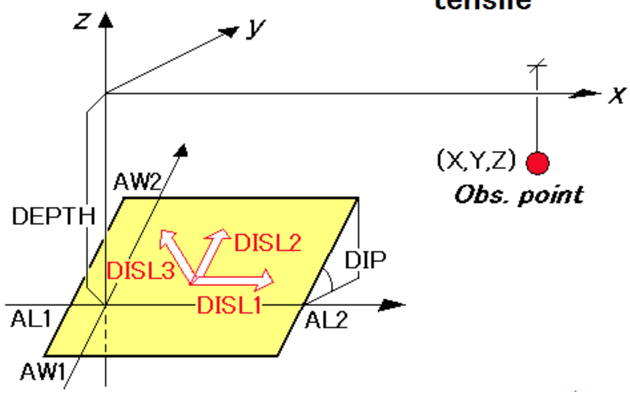
AL1, AL2 : Coordinate range in strike direction of the fault surface
AW1,AW2 : Coordinate range in up-dip direction of the fault surface
taking reference point as the origin of the fault surface
DISL1 : Dislocation in strike-slip component
DISL2 : Dislocation in dip-slip component
DISL3 : Dislocation in tensile component
If 0<DIP<90, positive DISL1 gives left-lateral movement
and positive DISL2 gives reverse-fault movement
while positive DISL3 gives open-type movement



Output arguments (REAL*4)

UX, UY, UZ : Displacement
UXX,UYX, UZX : X-derivative
UXY, UYY, UZY : Y-derivative
UXZ, UYZ, UZZ : Z-derivative

IRET : Return code
: =0...normal
: =1...singular point
: =2...positive Z was given



(IRET=1 occurs when the observation point lies on the fault edges)

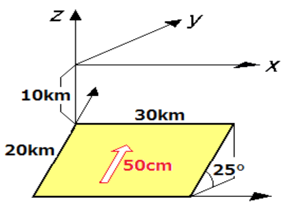
(2) Unit of output

Unit for UX,UY,UZ = (Unit of DISL)
Unit for UXX..UZZ = (Unit of DISL) / (Unit of X,Y,..,AW2)

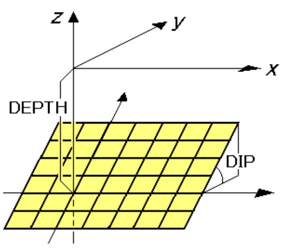
So, if dislocation is given in unit of cm and X, Y, Z, DEPTH, AL1, AL2, AW1, AW2 are given in unit of km, UX,UY,UZ(in cm) can be obtained by output itself, while UXX, UYX,...,UZZ in correct unit can be obtained by multiplication of 10**(-5).

(3) Subroutines called by DC3D : DCCON0, DCCON2, UA, UB, UC

A sample of parameters
AL1=0, AL2=30, AW1=−20,AW2=0,
DEPTH=10, DIP=25, DISL2=50



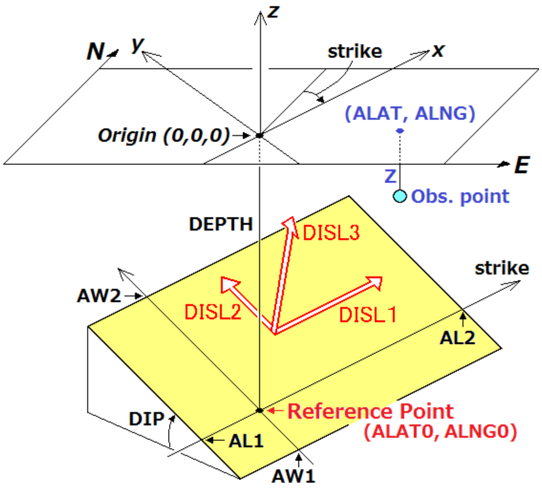
By adopting AL1, AL2, AW1, AW2, this subroutine can be easily applied to inhomogeneous source, i.e. a source composed by multi segment faults, each of which may have different dislocations.



Appendix-1 : Fault model in a geographical coordinate system

A geographical coordinate system may be adopted in actual application.
In such a case, follow the steps below.

(1) Select reference point on the fault surface
as (ALAT0, ALNG0).
(2) Convert station's coordinate, (ALAT, ALNG)
to EW and NS position, (XEW, YNS) using
the subroutine, PRTOXY.
(3) Convert (XEW, YNS) to the position (X, Y)
In the fault coordinate system according
To the strike direction.




```
      SUBROUTINE PRTOXY ( ALATDG, ALNGDG,  ALATO, ALNGO,  X, Y,  IND )
C
C**************************************************************
C*****                                                    *****
C*****   Conversion between (lat, long) and (X, Y)        *****
C*****                  using Gauss-Krueger projection    *****
C*****                                                    *****
C**************************************************************
C
C***** Input/Output
C*****   ALATDG, ALNGDG : latitude, longitude (deg)
C*****   X      ,   Y   : EW, NS coordinates  (km)
C
C***** Input
C*****   ALATO, ALNGO : origin of projection (deg)
C*****   IND : =0 ... transform (lat, lng) to ( X , Y )
C*****       : =1 ... transform ( X , Y ) to (lat, lng)
C
      parameter ( A=6378.160, E2=6.6946053E-3,  E12=6.7397251E-3 )
      parameter ( D=57.29578, RD=1./57.29578 )
C-------------------------------------------------
C----- IND=0 : transform (lat, lng) to (X, Y) -----
C-------------------------------------------------
      IF (IND .EQ. 0)  THEN
          RLAT = ALATDG*RD
          SLAT = SIN( RLAT )
          CLAT = COS( RLAT )
          V2   = 1. + E12*CLAT*CLAT
          AL   = ALNGDG - ALNGO
          PH1  = ALATDG + 0.5*V2*AL*AL*SLAT*CLAT*RD
          RPH1 = PH1*RD
          RPH2 = (PH1 + ALATO)/2.*RD
          SRPH1 = SIN( RPH1 )
          SRPH2 = SIN( RPH2 )
C-----
          R  = A*(1. - E2) / SQRT( 1. - E2*SRPH2*SRPH2 )**3
          AN = A / SQRT( 1. - E2*SRPH1*SRPH1 )
          C1 = D / R
          C2 = D / AN
          Y  = (PH1 - ALATO) / C1
          X  = AL*CLAT/C2*( 1. + AL*AL*COS(2.*RLAT)/(6.*D*D) )
C-------------------------------------------------
C----- IND=1 : transform (X, Y) to (LAT, LNG) -----
C-------------------------------------------------
      ELSEIF(IND .EQ. 1)  THEN
          RLATO = ALATO*RD
          SLATO = SIN( RLATO )
```

```
          CLAT0 = COS( RLAT0 )
          DEN = SQRT( 1. - E2*SLAT0*SLAT0 )
          R  = A*( 1. - E2 ) / DEN**3
          AN = A / DEN
          V2 = 1. + E12*CLAT0*CLAT0
C-----
          C1 = D / R
          C2 = D / AN
          PH1  = ALAT0 + C1*Y
          RPH1 = PH1*RD
          TPH1 = TAN(RPH1)
          CPH1 = COS(RPH1)
          BL   = C2*X
          ALATDG = PH1 - 0.5*BL*BL*V2*TPH1*RD
          ALNGDG = ALNG0+BL/CPH1*(1.- BL*BL*(1.+2.*TPH1*TPH1)/(6.*D*D))
      ENDIF
C-----
      RETURN
      END
```

Appendix-2 : Test routine to check displacement calculation by DC3D

```
C----- Check DC3D
      X=10.
      Y=20.
      Z=-30.
      DEPTH=50.
      DIP=70.
      AL1=-80.
      AL2=120.
      AW1=-30.
      AW2=25.
      DISL1=200.
      DISL2=-150.
      DISL3=100.
C-----
      WRITE(6,*) '*** OUTPUT OF DC3D ***'
      WRITE(6,*)
      WRITE(6,*) 'DEPTH,DIP=',DEPTH,DIP
      WRITE(6,*) 'AL1,AL2,AW1,AW2=',AL1,AL2,AW1,AW2
      WRITE(6,*) 'DISL1,DISL2,DISL3=',DISL1,DISL2,DISL3
      WRITE(6,*) 'X=',X,'  Y=',Y,'  Z=',Z
C-----
      ALPHA=2./3.
      CALL  DC3D(ALPHA,X,Y,Z,DEPTH,DIP,
     *             AL1,AL2,AW1,AW2,DISL1,DISL2,DISL3,
     *             UX,UY,UZ,UXX,UYX,UZX,UXY,UYY,UZY,UXZ,UYZ,UZZ,IRET)
      WRITE(6,*)
      WRITE(6,*) 'IRET=',IRET
      WRITE(6,*) 'UX,UY,UZ=',UX,UY,UZ
      WRITE(6,*) ' ANSWER =  -37.8981  63.1789  14.9607'
      STOP
      END
```

Yoshimitsu OKADA

Natl.Res.Inst. for Earth Sci. & Disas.Prev.
Tennodai 3-1, Tsukuba, Ibaraki, 305-0006 JAPAN
TEL : +81-29-863-7771,   FAX : +81-29-863-7770
e-mail : okada@bosai.go.jp