MWRT 编译安装和使用

1. MWRT 简介

MWRT(Microwave Radiative Transfer)为刘国胜老师设计的平面平行微波辐射传输模式，下载地址：http://cirrus.met.fsu.edu/

2. MWRT 编译和安装

（参考安装包中的 readme 文件）

1. 解压软件包

$ tar zxvf mwrt.tar.gz

2. 设置编译选项

可根据需要修改 MWRT 程序目录下 makefile 文件

比如 **FC = gfortran** 可以修改为自己需要的编译器

3. 编译软件

$ make all

如果编译正确，bin 目录下会生成 4 个可执行文件

mwrt_modair

mwrt_getwtr

mwgt_getpw

mwrt

4. 设置环境变量

vi ~/.bashrc

export MWRT=/d0/jjliu/opt/mwrt

export PATH=$MWRT/bin:$PATH

/d0/jjliu/opt/mwrt 根据实际安装路径修改

$ source ~/.bashrc

5. 运行测试

MWRT 目录 test 路径下，运行

$ ./chk

```
The Differences Between Your Results and The Test-Suite:
None. Congratulations !
```

若结果如上，则表明安装成功。

3. MWRT 运行

MWRT 的运行可以有两种方式：

1. Shell 脚本运行
2. 直接调用 fortran 子程序运行

3.1 shell 脚本运行

即通过命令行形式运行 MWRT
运行 mwrt 命令至少需要两个 ascii 文件，一个是 atmospheric profile，一个是 hydrometeors profile，还可以添加其他参数，若不添加，即是缺省值。这些参数以及缺省值值可以通过 mwrt -h 查看。如下所示：

```
$ mwrt -h
HELP MENU FOR MWRT
 Syntax: mwrt [OPTIONS]
 OPTIONS: [Default]
 -f Freq
                Freq=frequency in GHz [18.9]
 -l Number_of_Layers
                Number of Layers          [-1 determined byAtmospheric Profile]
 -lout OUT_LAYER
                Which to output           [1=TOA]
 -ihv OUT_POL
                1=V 2=H 0=both             [0]
 -u U
                cosine of zenith angle[0.60]
  Negative means downward radiation
 -wtr CLD_PRECIP_F
                Filename of hydro's      [.wtr]
 -air AIR_F
                Filename of Atmosphere's
                                           [.air]
 -ts   STemp
                Surface Temp in K         [300.]
 -surf SType
                  Surface Type              [0]
     0:ocean 1:land 2:seaice 3:snowcover
 -slnty Salinity
  for    ocean only,in per thousand [35.]
 -surf_ems EMS
  for land only, surf emissivity    [0.9]
 -surf_icetype ITYPE
  for seaice only,                  [2]
  0:new 1:2nd_year 2:multiyear
 -surf_snowtype SWType
  for snowcover surface only,       [1]
```

0:wet 1:dry 2:refrozen
-wind WIND
sea surface wind speed in m/s [0.]
-icemodel IceModel
for cloud ice, ['midlat']
Choice are: tropics, midlat
-iceshape IceShapeNumber
for cloud ice shape 0-10, [9]
-snowmodel SnowModel
for snowfall size distribution, ['SS']
-snowshape SnowShapeNumber
for snowflake shape 0-10 [9]
-graupeldensity DEN_GRAUPEL
for graupel precip [-1]
density for falling graupels in g/cm3
-outfile OUTFILE [stdout]
Filename for output
-SurfModel MODEL ['F']
Choose from 'Lambertian' and 'Fresnel'
-MixingRule RULE (for graupel) ['MG']
MG/mg: Maxwell-Garnet
LL/ll/DB/db:Lorentz-Lorenz or Debye
EV/ev: Equivalent volume (solid sphere)
EM/em/BR/br:Equivalent Media or Bruggeman
-RorW R/W [R]
the values given in wtr file are rainrate or water content
If the values are water contents, use [W]ater

大气廓线和水凝物扩线：

1）大气廓线

大气廓线包含：高度，压强，温度，水汽含量廓线

大气廓线文件可以根据自己的需要自己编写，程序本身也给出了一些标准廓线，在～/mwrt/profiles文件夹里(大气廓线的说明可以查看~/mwrt/profiles/_inventory.dat)：

A0 :US Standard Atmosphere with 1 km resolution

A1 :Tropical Standard Atmosphere with 1 km resolution

A2 :15 Degree Winter with 1 km resolution

A3 :15 Degree Summer with 1 km resolution

A4 :45 Degree Winter with 1 km resolution

A5 :45 Degree Summer with 1 km resolution

A6 :60 Degree Winter with 1 km resolution

A7 :60 Degree Summer with 1 km resolution

B0 :US Standard Atmosphere with 0.5 km resolution

B1 :Tropical Standard Atmosphere with 0.5 km resolution

B2 :15 Degree Winter with 0.5 km resolution
B3 :15 Degree Summer with 0.5 km resolution
B4 :45 Degree Winter with 0.5 km resolution
B5 :45 Degree Summer with 0.5 km resolution
B6 :60 Degree Winter with 0.5 km resolution
B7 :60 Degree Summer with 0.5 km resolution
C0 :US Standard Atmosphere with 0.2 km resolution
C1 :Tropical Standard Atmosphere with 0.2 km resolution
C2 :15 Degree Winter with 0.2 km resolution
C3 :15 Degree Summer with 0.2 km resolution
C4 :45 Degree Winter with 0.2 km resolution
C5 :45 Degree Summer with 0.2 km resolution
C6 :60 Degree Winter with 0.2 km resolution
C7 :60 Degree Summer with 0.2 km resolution
snowfall-01.air :Derived fron 45 Degree Winter. Res. is 0.2km below 2km 1km above

大气廓线文件的第一行表示大气分层的层数，下面的四列分别表示高度，压强，温度，相对湿度。如snowfall-01.air(只列出了前5行)：

```
 31
        0.00    1018.00     273.40      90.00
      115.00    1015.00     273.50      84.00
      233.00    1000.20     272.70      85.00
      402.00     979.20     271.20      90.00
      ……
```

2）水凝物结构：

水凝物结构文件的含义以snowfall-gp.hyd为例说明：

文件内容：

```
"snowfall-01.air" 3 "LIN"
0.0 1.5    1.0 1.0    0.0 0.0 1.0    -10 -10
1.5 4.0    1.0 0.0    0.0 0.0 1.0    0.0 -10
4.0 15.0    0.0 0.0    0.0 0.0 0.0    -10 -10
```

第一行"snowfall-01.air"表示与大气廓线文件snowfall-01.air相匹配， 3表示大气分为3层，"LIN"表示使用的方法（不用管）。

第二行0.0 1.5表示大气第一层是从0到1.5公里，后面5列依次表示云水，云冰和雨，雪，霰所占的比例，最后两列我也不知道什么意思。。

3）水凝物含量廓线

水凝物含量廓线包含：云水，云冰，雨，雪，霰廓线

水凝物含量廓线文件需要通过命令mwrt_getwtr（使用方法可以通过命令mwrt_getwtr -h查看）得到，该命令可以通过设定的水凝物廓线结构获取与大气廓线匹配的水凝物含量廓线。

命令格式为

mwrt_getwtr .hyd文件 降水率

结果是得到一个名为.wtr文件（隐藏），也可以通过-o参数自定义输出文件名。

下面是两个shell脚本例子：

例子一：

```
#! /bin/bash
# Time-stamp: <heng 09/07/2012 10:01:31>
# Author:
# DescriPtion:
TB=TB.out
hyd=snowfall-gp.hyd
air=snowfall-01.air
echo -n > $TB
for rr in 5 10 15 20
do
mwrt_getwtr $hyd $rr -a $air -o WTR
for feq in 10 19 21 37 85
do
mwrt -f $feq -air $air -wtr WTR >> $TB
done
echo ""
done
```

例子二：

```
# Time-stamp: <2013-01-22 10:11:10 Test2.sh>
# Author:
# DescriPtion:
TB=TB2.out
hyd=snowfall-gp.hyd
air=snowfall-01.air
echo -n > $TB
SSWs=20
#  水凝物廓线
mwrt_getwtr $hyd 0 -a $air -o WTR
for feq in 6.9 10.7 23.8 36.5 89.0
do
for (( SSW=1; SSW<=SSWs; SSW++ ))
do
#  输出内容不换行
echo -n $feq $SSW >> $TB
#  运算
mwrt -f $feq -wind $SSW -air $air -wtr WTR >> $TB
done
done
echo "Done!"
```

输出结果为 RR(L), RS(L), RG(L), TW1, TW2, TBV, TBH
分别为 Rain rate, snowfall rate, graupel rate, liquid_water_path, ice_water_path，垂直极化，水平极化亮温（参考~/mwrt/readme）

3.2 调用 fortran 子程序运行

即直接调用**~/mwrt/radtrans/radsub.f** 程序
radsub.f 参数：

```
SUBROUTINE MWSTRM4 (F, L, LOUT, IHV, U, WC, WI, RR, &
      WR, RS, WS, RG, WG, PMB, TK, RH, Z, TS, IS, SLNTY, &
      WND, IceModel, IceShape, SnwModel, SnwShape, &
      DENGRP, MixingRule, TB, TW1, TW2, WK, SurfModel, IO)
```

输入参数	
F	频率(GHz)
L	层数
LOUT	输出亮温值所在层
IHV	极化方式 1=V, 2=H, else=BOTH
U	输出方向 正值向上，负值向下
WC	云液态水含量(g/m^3)
WI	云冰水含量(g/m^3)
RR	降水率(mm/h)，负值时使用 WR 参数
WR	雨水含量(g/m^3)
RS	降雪率(mm/h) ，负值时使用 WS 参数
WS	冰雪含量(g/m^3)
RG	降雹率(mm/h) ，负值时使用 WG 参数
WG	雹霰水含量(g/m^3)
PMB	气压(mb)
TK	气温(K)
RH	相对湿度(%)
Z	层顶高度(m)
TS	下垫面温度(K)
IS	下垫面类型，0=海洋, 1=陆地或指定的地面比辐射率, 2=海冰, 3=雪
SLNTY	IS=0 盐度 IS=1 比辐射率 IS=2 海冰类型 0=新冰 1=2 年冰 2=多年冰 IS=3 雪类型 0=干雪 1=湿雪 2=重结冰
WND	风速 (IS=0 时有效)
IceModel	云冰粒径分布'TROPICS','MIDLAT'
IceShape	冰粒外形 0 - 10 [integer]

SnwModel	雪粒径分布'SS', 'GM'
SnwShape	雪花外形 0 - 10 [integer]
DENGRP	雹霰密度 (g/m3 0<DENGRP<0.916)
MixingRule	雹霰混合方式 MG,LL/DB,EV,EM/BR
SurfModel	地表模式 Fresnel or Lambertian
IO	
输出参数	
TB	Brightness Temperature (K)
TW1	Total Integrated Liquid Water (Cloud And Rain)
TW2	Total Integrated Ice Water (Cloud Ice And Snow)
WK	

********** INPUT **********

F: Frequency in GHz
L: TOTAL NUMBER OF LAYERS
LOUT: Layer Number (top=1, bottom=L) at which TB will be outputed
IHV: 1=V-POL, 2=H-POL, else=BOTH
U: DIRECTION for OUTPUT, positive upward TB at layer top, negative downward TB at layer bottom

---

VERTICAL PROFILES: FIRST LAYER IS TOP, DOWNWARD, DIMENSION = L / L+1
Variables with dimension of L are average in a layer, L+1 are value at the top boundary
For example, WC(1) is the LWC averaged in the first (top) layer, while TK(1) is the Temp at TOA, TK(L+1) the air Temp at surface

WC: CLOUD LIQUID WATER CONTENT IN g/m3. WC(L)
WI: CLOUD ICE WATER CONTENT IN g/m3. WI(L)
RR: RAINFALL RATE IN MM/HR, negative if use WR. RR(L)
WR: rain water content in g/m3, not used in RR>0. WR(L)
RS: SNOWFALL RATE IN MM/HR, LIQUID WATER EQUIVALENT, negative if use WS. RS(L)
WS: snow water content in g/m3. not used if RS>0. WS(L)
RG: Precipitation rate for Graupel, liquid equav, negative if use WG. RG(L)
WG: graupel water content in g/m3. not used if RG>0. WG(L)
PMB: PRESSURE IN mb. PMB(L+1)
TK: TEMPERATURE IN K. TK(L+1)
RH: RELATIVE HUMIDITY IN %. RH(L+1)
Z: LAYER TOP ALTITUDE IN m. Z(L+1)

TS: SURFACE TEMPERATURE IN K
IS: SURFACE TYPE: 0 = OCEAN, 1 = LAND or SPECIFIED SURFACE EMISSIVITY, 2 = SEA

ICE, 3 = SNOW
SLNTY: (negative means using default)
  WHEN IS=0, SALINITY IN PER THOUSAND [35]
  WHEN IS=1, EMISSIVITY [0.9]
  WHEN IS=2, ICE TYPE:0=NEW,1=2ND YEAR, 2=MULTIYEAR [2]
  WHEN IS=3, SNOW TYPE: 0=WET, 1=DRY, 2=REFROZEN [1]

WND: WIND SPEED (ONLY USED WHEN IS=0)
ICEMODEL: Cloud Ice size distribution models, choose from: 'TROPICS' / 'tropics', 'MIDLAT' / 'midlat'
ICESHAPE: particle shape number: 0 - 10 [integer]
SNWMODEL: Snow Particle size distribution models, choose from: 'SS'/'ss', 'GM'/'gm'
SNWSHAPE: Snowflakes shape number: 0 - 10 [integer]
DENGRP: DENSITY FOR GRAUPEL in g/cm3 (0<DENGRP<0.916),negative for default value (see mwrt.inc)
MixingRule: Mixing Rule for graupel: MG,LL/DB,EV,EM/BR

SurfModel: "Fresnel" [default], or "Lambertian", character*1, Valid values are "I","L","f","F"
IO: set to 0 when call this program first time, and never change it

********** OUTPUT **********

TB(2): BRIGHTNESS TEMPERATURE (K)
  1= Vertical Pol
  2= Horizontal Pol
If IHV Specify only one pol, The other will be blank.
TW1: TOTAL INTEGRATED LIQUID WATER (CLOUD AND RAIN)
TW2: TOTAL INTEGRATED ICE WATER (CLOUD ICE AND SNOW)

下面分析一个例子（探究微波亮温大气柱水汽含量的敏感性），主程序为：

```
    Parameter (Maxl=75)
    REAL sff(6)
        REAL  mr(Maxl),mt(Maxl),qq(Maxl+1),ar(Maxl,10)
        DIMENSION WC(MAXL),WI(MAXL),RR(MAXL),RS(MAXL),PMB(MAXL+1),
     +    TK(MAXL+1),RH(MAXL+1),Z(MAXL+1),TB(2),WK(95*MAXL)
        DIMENSION WR(Maxl),WS(Maxl),RG(Maxl),WG(Maxl)
        CHARACTER ICEMODEL*7,SNWMODEL*2,MIXINGRULE*2,SURFMODEL*1
        INTEGER IceShape,SnwShape,IO
        DATA WC/Maxl*0.0/,WI/Maxl*0.0/
        DATA RR/Maxl*-1.0/,RS/Maxl*-1.0/
        DATA WR/Maxl*0.0/,WS/Maxl*0.0/
        DATA RG/Maxl*-1.0/,WG/Maxl*0.0/
```

```
          L=Maxl
          LOUT=1
          U=cos(3.1415926*53/180)
          IHV=9
          IS=1

          SURFMODEL='F'
          SNWMODEL='SS'
         SNWSHAPE=7
          IO=0
ccccccc  some useless parameter in this program CCC

          ICEMODEL='tropics'
          ICESHAPE=5
          MIXINGRULE='EV'
          DENGRP=-2

     open(25,file='/home/liujj/opt/mwrt/lib/profiles/C1',status='old')
     read(25,*) nn
     do i=1,Maxl+1
        read(25,*) z(Maxl+2-i),pmb(Maxl+2-i),tk(Maxl+2-i),rh(Maxl+2-i)
     enddo
     close(25)

     data sff/6.925,10.65,18.7,23.8,36.5,89.0/
     ts=295.0
     wnd=4.0
     slnty=0.9

ccccccccccccccc--output_file--ccccccccccccc

     open(40,file='./tb_cwv.txt')

c         do i=0,240
c    do i1=0,479
c    read(30,*) lon,lat,SLNTY
     do j=1,6
      f=sff(j)
     do j1=27,95,1
        do j2=1,maxl+1
         rh(j2)=real(j1)
        enddo
ccccccc Calculate Column Water Vapor ccccc
          wp=0.0
```

```
          do i=1,Maxl
          mt(i)=(tk(i)+tk(i+1))/2.0
          mr(i)=(rh(i)+rh(i+1))/2.0
c         if(i.eq.jk+1) mr(i)=rh(i+1)
c         if(i.eq.jk-1) mr(i)=rh(i)
          tm=7.5*(mt(i)-273.15)/(237.3+mt(i)-273.15)
          es=6.11*(10**tm)
          aa=es*mr(i)*217.0*2*0.001/mt(i)
          wp=wp+aa                          ! kg/m2
          enddo

      CALL MWSTRM4(F,L,LOUT,IHV,U,WC,WI,RR,WR,RS,WS,RG,WG,PMB,TK,
     1     RH,Z,TS,IS,SLNTY,WND,ICEMODEL,ICESHAPE,SNWMODEL,SNWSHAPE,
     1     DENGRP,MIXINGRULE,TB,TW1,TW2,WK,SURFMODEL,IO)
     write(40,100) f,wp,tb(1),tb(2)
     enddo
     enddo
100     format(f8.3,3f15.8)

     close(40)
     stop
     end
```

该程序的目的是探究亮温对 CWV（大气柱水汽含量）的敏感性，需要注意的是，输入的是 rh（相对湿度），需要做一个转化：

$$e_s = e_{s0} 10^{\frac{at}{b+t}}$$

$$e = e_s * rh$$

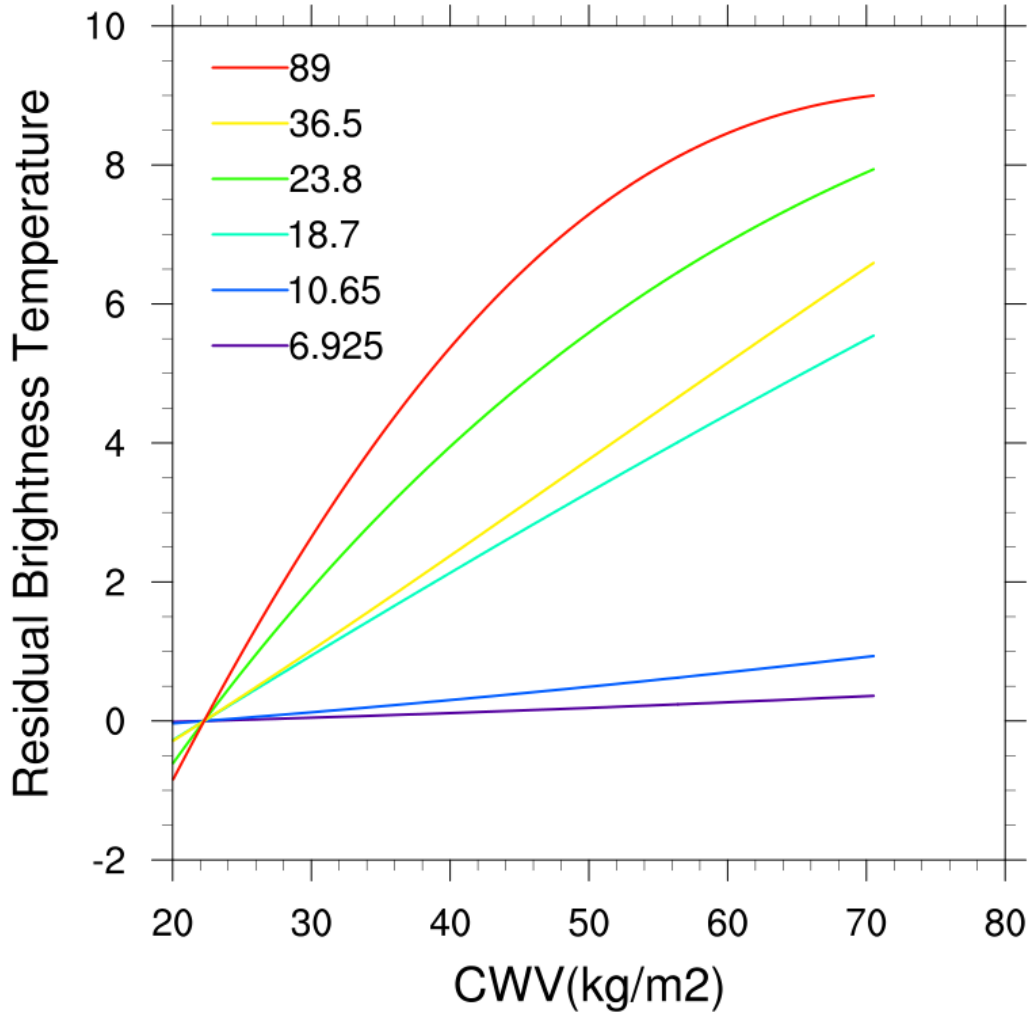
$$\rho_V = \frac{e}{R_V T} = \frac{\varepsilon e}{R_d T}$$

（《大气物理学》盛裴轩 p21-p22）

设该主程序文件名为 tb_cwv.f，编译命令：

f95 tb_cwv.f /home/liujj/opt/mwrt/src/rdcmd.c -L /home/liujj/opt/mwrt/lib/ -lrad -lmwrt -llap -o tb_cwv.exe

运行结果：



4.最新版 MWSIM

最新版的微波辐射传输模式名为 MWSIM，但最后一步 test 时，出现如下结果：

```
[jjliu@LIUJJ test]$ ./chk
The Differences Between Your Results and The Test-Suite:
2,6c2,6
< 19GHZ:     10200.0    7100.9 241.38 241.38
< 37GHZ:     10200.0    7100.9 195.97 195.97
< 89GHZ:     10200.0    7100.9 150.21 150.21
< 150GHZ:    10200.0    7100.9 135.04 135.04
< 3GHz:   -9999.9 -9999.9    22.1    25.2    23.1    28.4    35.4    42.8    42.9    42.9    47.9    47.9
 47.9    47.9    47.9
---
> 19GHZ:     10200.0    7100.9 241.51 241.51
> 37GHZ:     10200.0    7100.9 195.98 195.98
> 89GHZ:     10200.0    7100.9 150.11 150.11
> 150GHZ:    10200.0    7100.9 134.95 134.95
> 3GHz:   -9999.9 -9999.9    22.1    25.2    23.1    28.3    34.9    42.3    42.3    42.4    47.9    47.9
 47.9    47.9    47.9
8,10c8,10
< 6GHz:   -9999.9 -9999.9    23.7    26.7    22.9    28.2    34.9    42.4    42.4    42.4    48.4    48.3
 48.3    48.3    48.3
<       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.1     0.6     1.0     1.4
   1.8     2.2
< 10GHz:  -9999.9 -9999.9    21.2    24.3    22.5    27.5    33.9    41.4    41.4    41.4    49.7    49.8
 49.9    50.0    50.1
---
> 6GHz:   -9999.9 -9999.9    23.7    26.7    22.9    28.1    34.6    42.0    42.0    42.0    48.4    48.3
 48.3    48.3    48.3
```

还不知道是什么原因……