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## RETRIEVAL OF SEA SURFACE HUMIDITY AND BACK RADIATION FROM SATELLITE DATA

P.V. SATHE<sup>@</sup> AND P.M. MURALEEDHARAN

National Institute of Oceanography, Goa 403004, India

<sup>@</sup>Corresponding author : sathe@darya.nio.org

### ABSTRACT

The paper presents a procedure and a software package to compute the sea surface humidity and atmospheric back radiation over the sea from satellite data. These parameters play an important role in air-sea exchange of heat, which in turn, determines the climate. Presently, there are no satellite sensors designed to retrieve them directly by remote sensing. This requires us to depend on *in situ* data, which are relatively sparse. We present a procedure in this paper that uses emission characteristics of sea surface in the microwave region of electro-magnetic spectrum to retrieve these parameters. A suite of computer programs developed for the purpose are also presented in the paper with their complete source code. The procedure is based on an algorithm originally proposed by Schlüssel in 1995. We have presented results for surface humidity and back radiation over the Arabian sea for the year 2000 and have shown them to be in agreement with the atmospheric and oceanographic processes operating during the corresponding seasons.

### Introduction

Sea surface humidity and atmospheric back radiation on the sea are two important parameters that are required in the determination of the heat budget of the oceans. The very presence of humidity on the sea surface indicates that the sea has lost considerable energy in producing the humid air above it. Conversely, the humid air re-radiates heat back to the sea, thus, slowing down the rate at which the sea loses heat due to long-wave radiation.

Thus, the two parameters share a complex relationship, which in turn influences the heat budget.

With the advent of remote sensing, particularly the use of weather satellites, it was expected that direct computation of air-sea fluxes would become a routine exercise. This did not happen because satellite sensors do not directly retrieve humidity and back radiation at the sea surface. One needs to take recourse to *in situ* data to supplement

these parameters (Schulz *et al.*, 1997, Sathe and Muraleedharan, 1999). *In situ* data are not readily available on large scales. Liu and Niiler (1984) and Liu (1986) approximated monthly mean values of surface humidity from columnar water vapour content of the atmosphere. The method was later shown to be erroneous (Simonot and Gautier, 1989) for computing latent fluxes.

In the absence of a direct method to estimate these parameters from remote sensing, Schlüssel *et al.* (1995) suggested alternate ways to retrieve these parameters using the emission characteristics of sea surface in passive microwave channels. By analysis of simulated brightness temperatures in various channels of SSM/I against 1098 globally distributed values for surface humidity, and back radiation (collected under the Coupled Ocean Atmosphere Response Experiment, COARE), Schlüssel gave following retrieval models for the humidity  $Q$  and atmospheric back radiation  $F$  on the sea surface.

$$Q = -80.23 + 0.6295T_{19V} - 0.1655T_{19H} + 0.1495T_{22V} - 0.1553T_{37V} - 0.06695T_{37H} \quad (1)$$

$$F = -57 + 0.945\sigma T_{22V}^{**4} + 0.580\sigma (T_{22V}^{**4} - T_{37H}^{**4}) + 1.827\sigma (T_{85V}^{**4} - T_{22V}^{**4}) \quad (2)$$

where  $\sigma$  is the Stefan Boltzmann constant with a value of  $5.67051 \times 10^{-8}$  (Rybicki and Lightman, 1979) and  $T_{19}$ ,  $T_{22}$ ,  $T_{37}$  and  $T_{85}$  are SSM/I brightness temperatures at 19, 22, 37 and 85 Ghz respectively, at horizontal (H) and vertical (V) polarization (see section on data for details).

In this paper, we describe a complete procedure and present a suite of computer programs to retrieve the above two parameters by making use of archived satellite data in microwave channels as explained above. Our procedure can extract data from any region of the earth and align the results along the geographical latitudes and longitudes to facilitate the formation of an image. We have presented the source code of all our programs to facilitate users to make necessary changes in the software to suit their purpose. Typical results produced by our method are shown in Tables 1 and Figure 4.

#### Data Used

The passive microwave satellite data originating from the sensor SSM/I, the Special Sensor

**Table 1:** Latitude and longitude values are in decimals multiplied by 100. Hum-1 and Hum-2 are humidity values in gm/kg in ascending and descending modes respectively, Rad-1 and Rad-2 are back radiation values in watts /m\*\*2 in ascending and descending modes respectively, Av.Hum and Av.Rad are average values for humidity and back radiation for the day and Tim-1 and Tim-2 are times in decimal hours multiplied by 10 for ascending and descending pass.

Lat.	Lon.	Hum-1	Hum-2	Rad-1	Rad-2	Av.Hum	Av.Rad	Tim-1	Tim-2
1709	5671	19.85	20.58	411.87	426.88	20.22	419.38	17	145
1698	5728	19.32	20.17	396.87	431.42	19.74	414.15	17	145
1516	8264	21.03	19.60	433.90	440.87	20.32	437.39	0	128
1505	9736	21.27	21.69	443.60	449.76	21.48	446.68	239	110
1389	3214	20.42	28.52	462.44	216.44	24.47	339.44	34	162
1320	5786	18.70	20.90	393.77	429.94	19.80	411.85	17	145
1160	8248	21.86	20.72	435.22	436.97	21.29	436.10	0	128
1113	9752	21.06	22.08	444.58	443.91	21.57	444.24	239	110

Microwave/Imager (Hollinger, 1988) have been used to realize the objectives of the study. The SSM/I has been operating continuously for the past two decades since its maiden launch in 1987 on board DMSP-8. This has made SSM/I data the first choice of oceanographers and meteorologists working in passive microwave radiometry (Gautam *et al.*, 2005, Faccani *et al.*, 2005, Singh *et al.*, 2004, Nystuen *et al.*, 1993). SSM/I measures microwave emission of sea in four spectral channels, namely, 19, 37, 22 and 85 GHz. It measures radiation in both vertical and horizontal modes of polarization except for 22 GHz, wherein; it measures only in vertical mode. Each channel generates two data sets everyday, one for each mode (except 22 GHz). Thus, we have 7 sets of SSM/I data ( $3 \times 2 + 1$ ) coming from 4 channels. The SSM/I scans the earth during both the ascending and descending modes. Thus, we have 14 data sets every day, 7 for ascending and 7 for descending mode.

The passive microwave satellite data are readily available from institutions such as the Remote Sensing Systems, Santa Rosa, California (Wentz 1991), National Snow and Ice Data Center, Boulder,

University of Colorado, USA ([http://nsidc.org/data/docs/daac/nsidc0032\\_ssmi\\_ease\\_tbs.gd.html](http://nsidc.org/data/docs/daac/nsidc0032_ssmi_ease_tbs.gd.html)), or the National Remote Sensing Agency, Hyderabad, India (<http://www.nrsa.gov.in>). In many cases, data are supplied free of cost. Archived microwave data from SSM/I are available as brightness temperature ( $T_B$ ) files for everyday of the year from Remote Sensing Systems, Santa Rosa, California, USA. They are commonly known as Wentz data. These files contain data as 2-byte unsigned integers whose values range from 550 to 3200. These values refer to a range of  $T_B$ 's varying from 55 to 320 K. Data from all channels are collocated to give a uniform resolution of 25 km on the ground.

These data are available in the form of gridded maps of the earth. They comprise of two azimuthal equal-area projections, for the northern or southern hemispheres, and one global cylindrical equal-area projection for the entire earth (see figures 1, 2 and 3 for the three projections). For details of these projections, see "EASE-Grid: A Versatile Set of Equal-Area Projections and Grids" under [http://nsidc.org/data/ease/ease\\_grid.html](http://nsidc.org/data/ease/ease_grid.html).



Fig. 1. The North azimuthal equal-area map

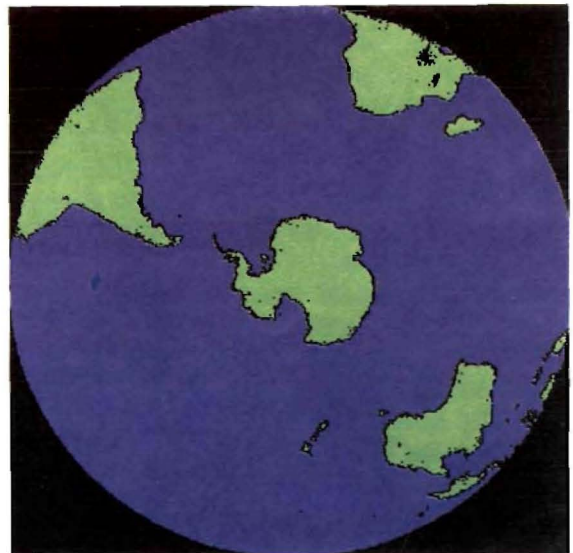


Fig. 2. The South azimuthal equal-area map

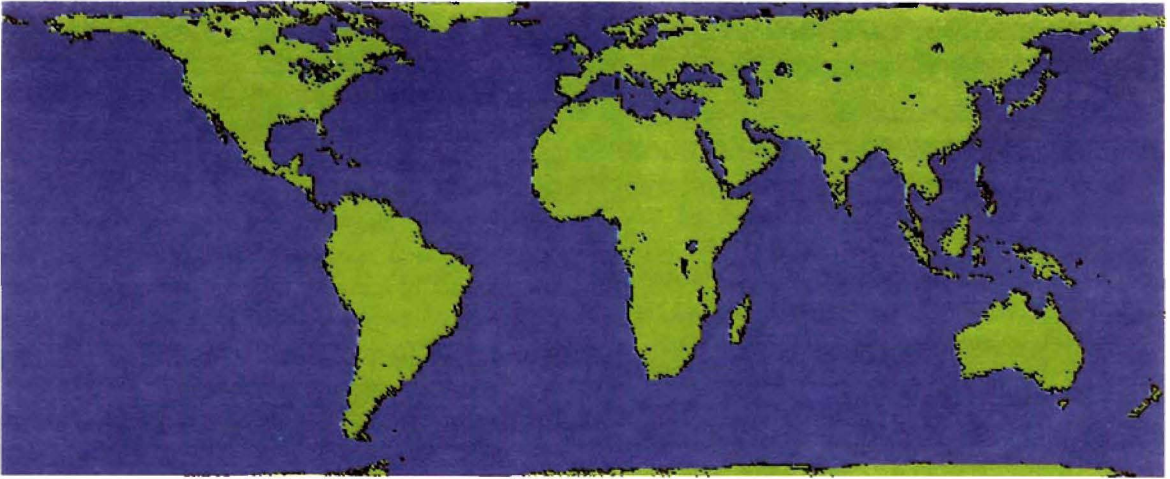


Fig. 3. The cylindrical equal-area map

### Procedure

The procedure begins with preparing data on microwave brightness temperatures in various channels ( $T_B$ 's) over the region of interest. In all, we need 9 values for every footprint on the earth. They are 6 values for  $T_B$ 's (19v, 19h, 22v, 37v, 37h, and 85v), 2 values for geo-location (latitude and longitude) and 1 value for the time of satellite pass.

Since the data are global in nature, we need to extract them over only those footprints that fall in our region of interest. Our software provides for extraction of data from a particular region on the earth, based on the latitudes and longitudes specified. Alternately, our software can be made to work for the entire earth.

We use equations 1 and 2 to compute the specific humidity at air temperature ( $Q$ ) and the atmospheric back scattered radiation ( $F$ ) respectively for every footprint from the corresponding set of  $T_B$ 's. The results are saved along with information on their location (latitudes and longitudes) and the time of satellite pass. Values for ascending and descending passes are separately computed and stored in the intermediate files.

In the second step, the values of  $Q$  and  $F$ , are re-organised to aid the formation of an image matrix, which can be correlated with a map of the region. In the final step of our procedure, we compare results in both ascending and descending swaths to locate common footprints (pixels) covered by them. For each common footprint, we compute mean values of humidity and back radiation.

The above procedure is accomplished by running the programs ONE to FOUR in their natural sequence (see Appendix 1 for the full source-code of these programs). Suitable comment cards are liberally used for the ease of readability. Users are free to change any part of the source code to suit their special needs.

The software needs huge space to store hundreds of input and output files generated while studying a region over a period of time. A disk of 10 GB can easily run out of space if one studies a region through different seasons. It would be a good practice to store results as binary files and delete unwanted files as soon as they have served their purpose.

## Software

### Program ONE

This is the basic program that converts the microwave brightness temperatures into geophysical parameters. As explained earlier, the program needs 9 input files, 6 for TB's, 2 for location and one for time. All files are binary. TB values are two-byte integers. If the software is run on UNIX systems, we need to swap their bytes. Time files are single-byte integers. Geolocation files are common to all data belonging to a given projection, namely, the azimuthal equal area projection in our case. We do not need to refresh them with every dataset.

Care needs to be taken to ensure that all data files chosen for one run of the software belong to the same date, are of the same resolution and are in the same mode (ascending or descending). We follow the convention that all input file names chosen for a given run begin with letter 'q' (see source code). This is with a view to differentiating them with a host of other input and output files that may reside in the same directory. The program creates only one output file. The software is so arranged that output of one program becomes input for the next program.

It is expected that user would be running the entire software in the same directory. This leads to dealing with hundreds of files, some input, some output, some byte-swapped, some un-swapped, some intermediate, some scratch-files etc. One needs to follow strict file management practices, which include naming/renaming files, deleting the unwanted ones and shifting some to other directories.

### Program TWO

Program Two is to be run immediately after program One. It uses the output of program One. It is advised that all the 9 files prepared earlier as inputs for program One (beginning with the letter

'q') may be deleted at this stage for the sake of clarity and space constrain.

The program reprojects the results as an image-matrix by organising records in the order of decreasing latitudes and their fractions. This ensures that top of the matrix indicates north while the bottom indicates south. This helps overlay our results on a conventional map of the region.

The program has a provision to keep user informed of the status of its execution by displaying on the terminal, the value of the latitude being processed. This gives the user an idea on whether the software is on the right track as well as the amount of processing yet to be done by the program. One run of the program needs one input file and it creates one output file.

### Program THREE

Program Three is continuation of program Two. It aids formation of an image by organising data records in the increasing order of longitudes along with their fractions. This ensures that left of the data matrix will indicate west and the right will indicate east.

It may be noted here that the original data set is in azimuthal equal area projection for each hemisphere (see figures 1 and 2). It does not constitute a matrix that can be mapped to an image in UTM (Universal Transverse Mercator) projection. Hence the need to reproject the extracted data.

One execution of the above programs creates one output file per mode. Since there are two modes, ascending and descending, programs One, Two and Three need to be run separately for each mode.

### Program FOUR

Program Four needs two input files, one for results of ascending mode, and the other for results of descending mode. Both files are created by



program Three (one in each run). The program examines the results of both modes and identifies common pixels that were covered by the satellite in both swaths. When it finds them, it lists their locations and average values. Besides, the program lists individual values from both modes separately. Should a doubt arise regarding authenticity of results, individual listings become important.

It is important to note that the swaths of the ascending and descending modes have a different geometry on the ground. It is only when they overlap, mean values can be computed for any parameter. We have shown some typical results for both ascending and descending passes, their mean and the time of satellite pass in table 1 for a few footprints.

The program generates one output file per run for the entire region of interest.

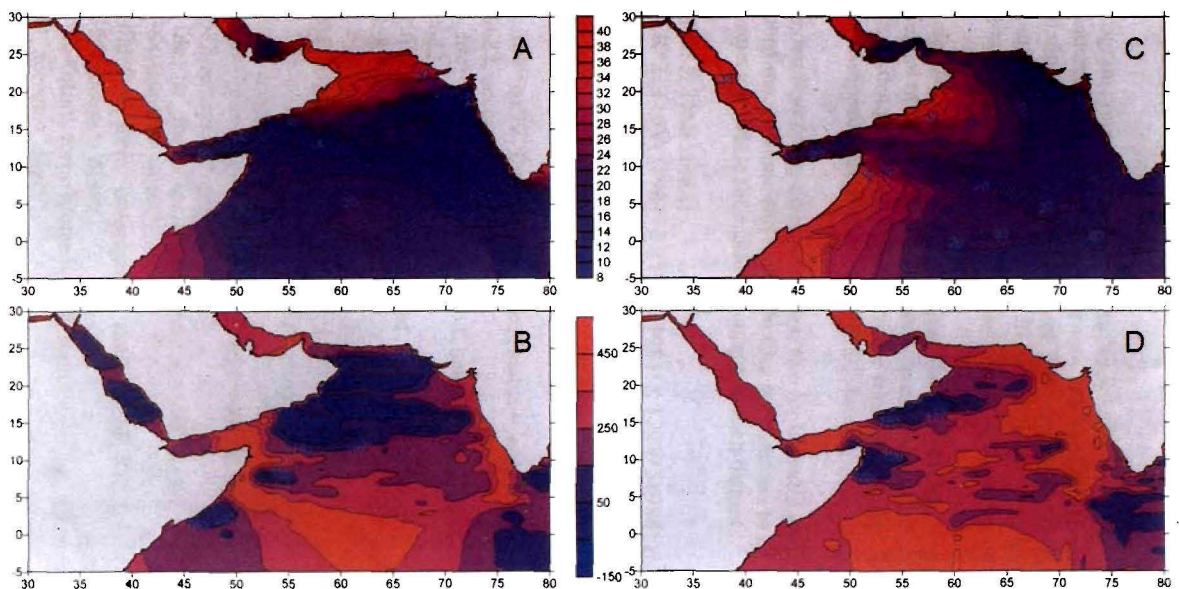
### Results and Discussion

The procedure and the suite of programs developed by us can be used to retrieve specific

humidity and atmospheric back radiation over any region of the earth from the archived data in passive microwave channels. For example we present here results over the Arabian sea for two contrasting seasons, namely, January and July for the year 2000.

January represents winter monsoon when north east winds make the region dry except in the north where dry continental air induces strong evaporation (Fig. 4A). This localised evaporation is too weak to produce convective clouds. Southern Arabian sea is exposed to the trajectory of north east monsoon and hence humidity levels rise. This increased humidity and enhanced surface warming (due to proximity of equator) invokes convection. The increased back radiation in southern Arabian sea in Fig. 4B supports the above processes.

Entire wind system reverses in July resulting in strong south west winds over the Arabian sea. Atmospheric humidity over the western Arabian sea is very high as the low level jet brings moisture from south. This is evident in the high humidity layer



**Fig. 4.** Specific Humidity (g/kg) (upper panel) and atmospheric back radiation (W/sq m) (bottom panel) during January 2000 (left panel) and July 2000 (right panel)

observed along the coast of Somalia and Arabia in Fig. 4C. The intensity reduces off shore as it precipitates over the cool ocean. The advected moisture over the western Arabian sea does not promote convection, as the sea surface is cool. This again limits back radiation in the western bay as shown in Fig. 4D. Thus, the oceanographic and atmospheric processes support the validity of the results arrived at using our procedure.

### Conclusion

The sea surface humidity and atmospheric back radiation over the sea play an important role in air-sea exchange of heat and climate determination. Satellite sensors do not retrieve these parameters directly. Based on an algorithm developed by Schlüssel (1995), we have proposed a procedure and presented a complete software package to compute these parameters from archived microwave data on brightness temperature. We have shown typical results obtained using our procedure in Arabian sea in January and July 2000. Our results are in agreement with oceanographic and atmospheric processes observed in the corresponding seasons.

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### Appendix 1: Program listings

#### Program ONE

- C This Program computes specific humidity at air temperature Q and atmospheric  
 C back scattered radiation F \*from microwave brightness temperatures Tb.  
 C Computation of Q needs 5 input files of Tb's, namely 19v, 19h, 22v, 37v and  
 C 37h. Computation of F needs 3 input files namely, 22v, 37h and 85v. Thus  
 C the program needs 6 input files (22v and 37h are common in both lists).
- C When selecting a set of 6 input files from their parent directory, one needs to  
 C ensure that all of them belong to the same date, same resolution and in the same  
 C mode (viz., ascending or descending). These files are two-byte integers. Their bytes  
 C need to be swapped before using on a UNIX system.
- C The program also needs three more files, two for latitudes and longitudes  
 C and one for time. Latitude and longitude files are common to all data under  
 C a given projection while time files are unique to each dataset .

```

INTEGER*1 TIM(519841)
INTEGER*2 T19V(519841), T19H(519841), T22V(519841),
INTEGER*2 T37V(519841), T37H(519841), T85V(519841)
DIMENSION LAT(519841), LON(519841)
DOUBLE PRECISION a, b, c, aa, rad
  
```

```

open(11, file='q19v', form='unformatted', status='old', RECL=1 1039682, access='direct')
open(12, file='q19h', form='unformatted', status='old', RECL=1 1039682, access='direct')
open(13, file='q22v', form='unformatted', status='old', RECL=1 1039682, access='direct')
open(14, file='q37v', form='unformatted', status='old', RECL=1 1039682, access='direct')
open(15, file='q37h', form='unformatted', status='old', RECL=1 1039682, access='direct')
open(16, file='q85v', form='unformatted', status='old', RECL=1 1039682, access='direct')
open(17, file='lat', form='unformatted', status='old', RECL=1 2079364, access='direct')
open(18, file='lon', form='unformatted', status='old', RECL=1 2079364, access='direct')
open(19, file='qtim', form='unformatted', status='old', RECL=1 519841, access='direct')
  
```

```

read(11) (T19V(j), j = 1, 519841)
read(12) (T19H(j), j = 1, 519841)
read(13) (T22V(j), j = 1, 519841)
read(14) (T37V(j), j = 1, 519841)
read(15) (T37H(j), j = 1, 519841)
read(16) (T85V(j), j = 1, 519841)
  
```



```

read(17)(lat(j),j = 1, 519841)
read(18)(lon(j),j = 1, 519841)
read(19)(tim(j),j = 1, 519841)
do 1 i = 11, 19
close(i)
1 continue
aa = 0.0000000567051
open(21, file= 'out.dat', status = 'new')
Write(21,101)

do 10 j = 1, 519841
C The following three statements extract data for the north Indian ocean. If they
C are deleted, the output will be for the entire northern hemisphere of the earth.

D if((float(lat(j))/100000.0).gt.25.0) goto 10
D if((float(lon(j))/100000.0).gt.120.0) goto 10
D if((float(lon(j))/100000.0).lt.30.0) goto 10

wet = -80.23 + 0.6295*float(T19V(j))/10.0 - 0.1655*float(T19 IH(j))/10.0 + 0.1495*float(T22V(j))/10.0 -
0.1553*float(T37V(2j))/10.0 - 0.06695*float(T37H(j))/10.0
if(wet.lt.0.0) goto 10

a = float(T22V(j))/10.0
b = float(T37H(j))/10.0
c = float(T85V(j))/10.0
rad = -57.0 + 0.945*aa*(a**4) + 0.580*aa*((a**4) - (b**4))
1 + 1.827*aa*((c**4) - (a**4))
if(T22V(j).lt.1) goto 10

write(21,102) float(lat(j))/100000.0,float(lon(j))/100000.0,
2wet, rad, (tim(j)+127)
10 continue
close(21)
101 format(' latitude longitude surface bac
1k time*10/
2' degrees degrees humidity radiation
3 hours'//)
102 format(1x, 4f15.2, i10)
stop
end

```

---

### Program TWO

- C This program arranges values of specific humidity and back scattered radiation  
C in decreasing order of latitudes. This ensures that when results are viewed as an

- C image north points upwards and south points downwards. The input file for this  
 C program is same as the output of the earlier program ONE

```
DIMENSION XLAT(2000), XLON(2000), C(2000), D(2000)
DIMENSION ITIM(2000)
DATA Mtop, Mbot/24,0/
OPEN(52, FILE='out.dat', form='unformatted', status='new')
```

- C The following DO LOOP 500 controls the processing by letting the program  
 C choose one latitude at a time. It starts from upper limit Mtop and goes down to  
 C the lower limit Mbot which define northern Indian Ocean in the present case.

```
DO 500 J = Mtop, Mbot, -1
OPEN(51, FILE='in.dat', status='old')
L=0
do 300 m = 1,4
read(51,*)
300 continue
```

- C The following DO LOOP 400 collects all values of a single latitude  
 C and the variable NUM remembers their serial number.

```
DO 400 K = 1, 30000
READ(51,100, END=15) BB, AA, CC, DD, it
IF(INT(BB).EQ.J) THEN
L = L + 1
XLAT(L) = BB
XLON(L) = AA
C(L) = CC
D(L) = DD
ITIM(L) = it
ENDIF
400 CONTINUE
15 CLOSE(51)
```

- C The following DO LOOP 430 organizes all values of a single latitude  
 C in the decreasing order their fractions (minutes/seconds etc).

```
DO 430 NEW = 1, L
X = -370.0

DO 420 N=1,L
A = XLAT(N)
IF(A.GT.X) NBIG = N
X = AMAX1(A,X)
```

```

420 CONTINUE

    WRITE(52),XLAT(NBIG),XLON(NBIG),C(NBIG),D(NBIG),
1 ITIM(NBIG)

    XLAT(NBIG) = -360.0
430 CONTINUE
    WRITE(6,602)j

500 CONTINUE
    CLOSE(52)
602 FORMAT(5X,'Sorting for 'I3'th latitude is over')
100 format(1x, 4f15.2, i10)
    STOP
    END

```

---

### Program THREE

- C This program arranges values of specific humidity and back scattered radiation  
C in the order of increasing longitudes to aid formation of image. The dataset is  
C already arranged in the order of decreasing latitudes by the earlier program  
C TWO whose output is the input for this program. Output of this program  
C THREE serves as output for the next programme FOUR

```

DIMENSION XLAT(1000), XLON (1000), C(1000), D(1000)
DIMENSION ITIM(1000)
OPEN(52, FILE='in.dat',form='unformatted', status='old')
READ(52) XLAT(1), XLON(1), C(1), D(1), ITIM(1)
J1 = 1
OPEN(53, FILE='out.dat',status='new')
Write(53,101)

```

- C This DO LOOP 50 is the controlling loop in the program. The values of J1 and  
C J2 mark the beginning and end of a group of values having the same latitude.

```

DO 50 J = 2, 30000
READ(52,END=5) AA, BB, CC, DD, it
GOTO 10
5 NNN = 100
J2 = J1
GOTO 20
10 IF(AA.EQ.XLAT(1)) THEN
    J1 = J1 + 1
    XLON(J1) = BB
    XLAT(J1) = AA

```

```

C(J1) = CC
D(J1) = DD
ITIM(J1) = it
GOTO 50
ENDIF
J2 = J1

```

C The following DO LOOP 45 arranges all longitudes of a given latitude in  
C decreasing order and writes them in the output file one by one.

```

20 DO 45 L = 1, J2
A = 210.0

```

C The following DO LOOP 40 is inside the DO LOOP 45. Its job is to  
C find the smallest longitude from the group having the same latitude.

```

DO 40 K = 1, J2
IF(XLON(K).LT.A) NSMALL = K
A = AMIN1(XLON(K),A)
40 CONTINUE

```

C The following part of the DO LOOP 45 writes the smallest longitude  
C found in the file. Once written, it makes it the biggest so that the  
C same longitude is not found again and again.

```

WRITE(53,100) , XLAT(NSMALL),XLON(NSMALL),C(NSMALL),
ID(NSMALL), itim(nsmall)
XLON(NSMALL) = 500.0
45 CONTINUE
IF(NNN.EQ.100) GOTO 55
J1 = 1
XLAT(J1) = AA
XLON(J1) = BB
C(J1) = CC
ITIM(J1) = IT
50 CONTINUE
55 CONTINUE
CLOSE(52)
CLOSE(53)

```

```

101 format(' latitude longitude surface bac
1 k time*10/
2' degrees degrees humidity radiation
3 hours'//)

```

```

100 format(1x, 4f15.2, i10)
STOP
END

```

---

#### Program FOUR

- C This program examines results obtained from both ascending and descending  
C modes for a given day. After examining, it chooses only those data that are  
C present in both ascending and descending modes and outputs them. The program  
C needs two input files, one for ascending mode and the other for of descending  
C mode.

```

Dimension alat(30000), blat(30000), alon(30000), blon(30000),
i awet(30000), bwet(30000), arad(30000), brad(30000), iatim(30
2 000), ibtim(30000)

```

```

open(11, file='in1.dat', status='old')
open(12, file='in2.dat', status='old')

```

```

do 2 mm = 1, 4
read(11,*)
read(12,*)
2 continue

```

- C The above DO LOOP 2 pushes read header beyond the captions and titles.

```

open(13, file='out.dat', status='new')
write(13,101)
write(13,102)

```

```

do 5 il = 1, 40000
read(11,100,end=6) alat(il),alon(il),awet(il),arad(il),iatim(il)
5 continue
6 k1 = il - 1
do 10 j1 = 1, 40000
read(12,100,end=11) blat(j1),blon(j1),bwet(j1),brad(j1), ibtim(j1)
10 continue
11 k2 = j1 - 1
close(11)
close(12)

```

- C Locating of the matching pairs begins  
do 50 i = 1, k1  
lat1 = int((alat(i))\*100.0)  
lon1 = int((alon(i))\*100.0)



```

do 40 j = 1, k2
lat2 = int((blat(j))*100.0)
lon2 = int((blon(j))*100.0)
if(lat1.ne.lat2) goto 40
if(lon1.ne.lon2) goto 40

```

```

write(13,200) lat1, lon1, awet(i), bwet(j), arad(i), brad(j),
1 (awet(i)+bwet(j))/2.0, (arad(i)+brad(j))/2.0, iatim(i), ibtim(j)

```

C Keeps writing the matching pairs, as it finds, one by one  
goto 50

```
40 continue
```

```
50 continue
```

```
stop
```

```
100 format(1x, 4f15.2, i10)
```

```
101 format(/,
```

```
1' Latitude and longitude values are in decimals multiplied by
```

```
2 100. Hum-1'/5x,'and Hum-2 are humidity values in gm/kg in ascenin
```

```
3 g and descending modes'/5x,'respectively, Rad-1 and Rad-2 are back
```

```
4 radiation values in watts/m**2 in'/5x,'ascending and descending
```

```
5 modes respectively, Av.Hum and Av.Rad are average'/5x,'values for
```

```
6 humidity and back radiation for the day and Tim-1 and Tim-2 are'/
```

```
7, 5x'times in decimal hours multiplied by 10 for ascending and desc
```

```
8 ending pass.'//)
```

```
102 format(5x,'Lat. Lon. Hum-1 Hum-2 Rad-1 Rad-2 Av.Hum
```

```
1 Av.Rad Tim-1 Tim-2'/)
```

```
200 format(1x, 2I7, 2F8.2, 2F9.2, 2F9.2, 2I7)
```

```
end
```

---