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Clear Sky Identification Using Data from Remote Sensing Systems at ARM's Southern Great Plains Site

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Introduction

Clouds profoundly affect our weather and climate due, in large part, to their interactions with radiation. Unfortunately, our understanding of these interactions is, at best, incomplete, making it difficult to improve the treatment of atmospheric radiation in climate models. The improved treatment of clouds and radiation, and a better understanding of their interaction, in climate models is one of the Department of Energy's Atmospheric Radiation Measurement (ARM) Program's major goals. To learn more about the distribution of water and ice, i. e., clouds, within an atmospheric column, ARM has chosen to use the remote sensing of clouds, water vapor and aerosols at its three climatologically-diverse sites as its primary observational method. ARM's most heavily instrumented site, which has operated continuously for more than a decade, is its Southern Great Plains (SGP) Central Facility, located near Lamont, OK. Cloud-observing instruments at the Central Facility include the Whole Sky Imager, ceilometers, lidar, millimeter cloud radar, microwave radiometers and radiosondes.

The Whole-Sky Imager (WSI) is one of ARM's premiere instruments for cloud detection (Shields, et al., 1990). The WSI is a ground-based, electronic imaging system, designed for acquiring images over the sky's dome through spectral (red, blue and infrared) filters. This system, which passively measures microwave emissions emanating from the sky, operates continuously. It normally acquires images once every 10 minutes. From these images, the distribution of clouds overhead can be determined from observed radiances (540 X 540 pixel resolution) using an automated cloud decision algorithm and related processing. After calibrating the 16-bit data, the algorithm calculates the ratios between the red and blue radiances and their corresponding background, or "cloud- and aerosol-free", values on a pixel-by-pixel basis. Pixels are cloudy or clear, depending on whether the ratios are less than or greater than prescribed thresholds. In forming these ratios, the program has historically relied on a library of clear sky ratio images. While the assemblage cover the necessary range of solar elevation and azimuth angles comprehensively, the library is, unfortunately, site dependent; that is, the images at the SGP site, painstakingly collected from many year's worth of data, are unsuitable for use at ARM's Tropical West Pacific and North Slopes of Alaska sites.

To liberate the WSI algorithm from its need to use site-dependent data, the Santa Barbara DISORT Atmospheric Radiative Transfer (SBDART) code has been adopted to estimate background (red and blue) radiances at any point on the earth's surface

(Ricchiazzi et al., 1998). SBDART is designed for analyzing a wide variety of radiative transfer problems encountered in satellite remote sensing and atmospheric energy budget studies. The program is based on a collection of highly developed and reliable physical models, which have been developed by the atmospheric science community over the past few decades. The discrete ordinate method provides a numerically stable algorithm for solving the equations of plane-parallel radiative transfer in a vertically inhomogeneous atmosphere. It is unclear, however, whether the assumption of plane-parallel radiative transfer yields satisfactory results when computing clear-sky radiation values, especially in the case of low sun angles. The aim of this work is to devise a set of procedures for identifying cloud-free days at the SGP site. Ultimately, such identifications will allow SBDART outputs to be validated as a function of angular distance from zenith via comparisons with WSI measurements of "pristine", daytime skies.

Identification of Clear Skies

For our purposes an ideal, or pristine, day is one in which the sky is free of clouds, and the aerosol load and moisture content in the atmosphere are low. The latter two factors were not explicitly considered in our study, but their effects could have been evaluated from the available data. Our procedures for identifying cloud-free days are based on the visualization and comparison of data from two of ARM's instruments, effectively co-located at the Central Facility: the Microwave Water Radiometer (MWR) and the Micropulse Lidar (MPL). The zenith-pointing MWR provides column-integrated amounts of water vapor and liquid water, approximately once every 30 seconds, while the MPL, a ground-based, optical remote sensing system for determining the altitude of clouds overhead, provides averages of cloud base heights once every 60 seconds. MWR and MPL data collections from January and February, 1999, and from July and August, 1999, were examined because of an interest in finding seasonal examples of cloud-free days at a continental location.

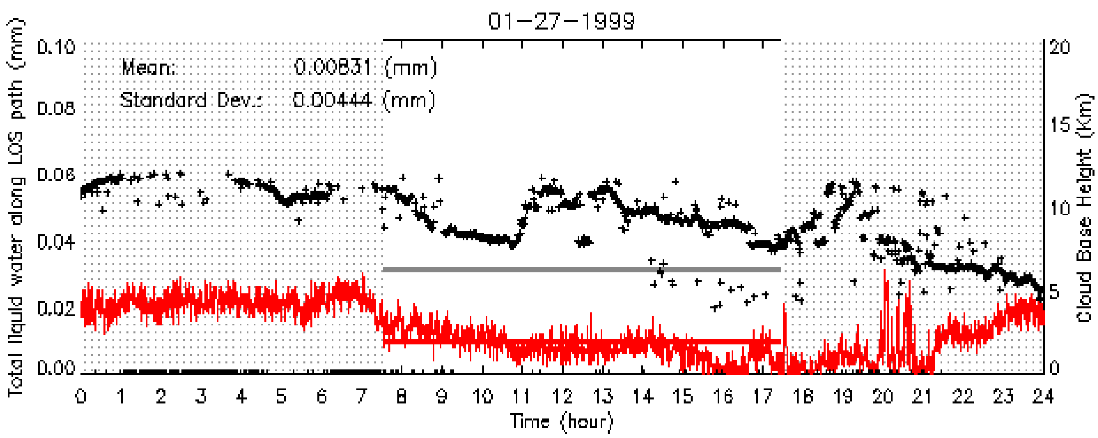
Data visualization offers the following outcomes:

1. The skies are clear, i.e., the liquid water path (LWP) values are small and constant, and no cloud base exists below the pure ice-phase level.
   Based on expert advice and personal experience, "small and constant" refers to hourly-averaged LWP values that are less than 0.03 mm (the retrieval noise threshold), and hourly-averaged standard deviations (STDs) that are less than 0.006 mm. Note that the MPL data are checked to make sure no ice-phase clouds are present.

2. The clouds are homogeneous, both in terms of droplet size and layer thickness; the LWP values are large, but their hourly-averaged STDs are small.

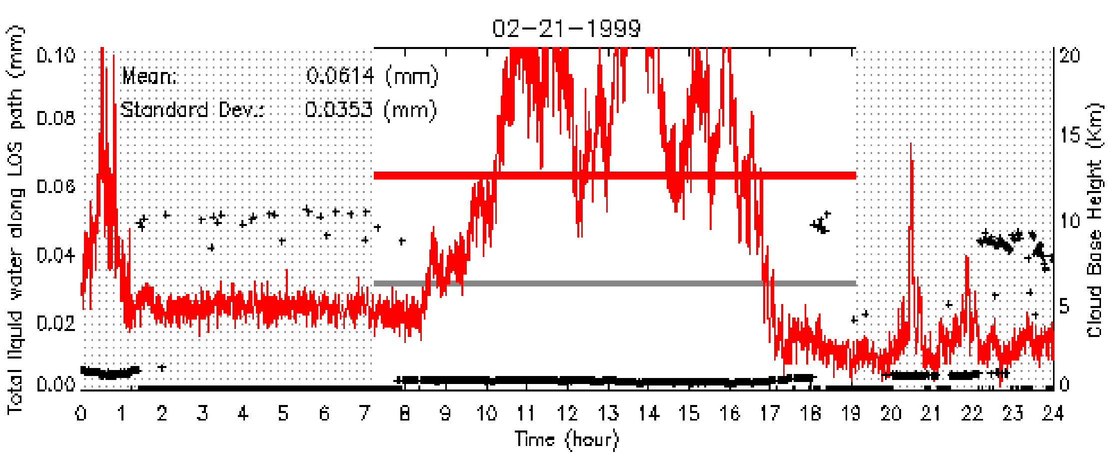
3. The clouds are variable, leading to large LWPs and STDs.

Examples of two cloudy scenarios are given below. In the first figure, dated 01-27-1999, the measurements of LWP made by the MWR, where LOS refers to line-of-sight, are plotted over a 24-hour period. However, since we have an interest only in daytime measurements (more specifically, those times at which the sun is five degrees, or more, above the horizon), stippled areas, corresponding to nighttime hours, have been added for purposes of delineation. The base heights of the cloud, which are indicated by plus signs, can be estimated from the scale on the right-hand axis. The gray horizontal bar, which spans the daylight hours, represents our chosen threshold (0.03 mm) for the LWP. The red horizontal bar, covering the same time period, represents the average of the LWP measurements during the daytime.



As can be seen, all LWP values fall below the 0.03 mm threshold…also indicated by the daytime mean and standard deviation of the MWR data in the upper left-hand corner of the plot…but they do so in the presence of a layer of cirrus clouds. This figure demonstrates the need to view both sets of data simultaneously, since the MWR is incapable of detecting ice crystals. The existence of a persistent cirrus deck means that the entire data set must be eliminated from consideration.

Like its predecessor the second figure, dated 02-21-1999, illustrates a cloud-filled sky, but one in which the clouds are composed of water, not ice.



Although weather observations are missing on this particular day, the cloud-height data suggest that fog settled over the Central Facility during the night, followed by a slight lifting during the day as a result, perhaps, of surface heating. The increase in condensation, as indicated by a rapid increase in the LWP values, may be due in turn to atmospheric heating. In any event, the combined data suggest that the entire day is unsuitable for our purposes.

In the tables below, we identify the days of the month (January, February, July and August of 1999) that satisfy our selection criteria. When a day is labeled "clear" (in the second column labeled "MWR + MPL"), the MWR-measured LWP must be less than 0.03 mm, its standard deviation must be less than 0.006 mm, and clouds cannot be present overhead, as detected by MPL, for most of the daylight hours. Notes in the third column refer to human weather observations made at the Central Facility. Like the Whole Sky Imager's view of the world, these observations encompass the entire sky, as opposed to the narrow fields of view obtainable with the MWR and MPL, so they may be quite useful, when available.

Month: January

Day	MWR+MPL	Observation	Pristine?
25	Clear	Mostly Broken	No
27	Clear	Clear, Cloudy and Broken	No

Month: February

Day	MWR+MPL	Observation	Pristine?
3	Clear	Clear form 7 to 11 a.m.	No
4	Clear	OK	Yes!
12	Clear	OK	Yes!
13	Clear	Scattered	No
14	Clear	No Data	No
15	Clear	Clear from 11 a.m. to 2 p.m.	No
17	Clear	Mostly Scattered	No
23	Clear	Clear from 11 a.m. to 4 p.m.	No
24	Clear	Clear from 7 a.m. to 1 p.m.	No
28	Clear	OK	Yes!

Month: July

Day	MWR+MPL	Observation	Pristine ?
5	Clear	OK from 11 a.m. to 2 p.m.	No
8	Clear	Scattered from 3 to 5 p.m. and from 8 to 9 p.m.	No
9	Clear	OK	Yes!
13	Clear	Obscured from 8 to 9 a.m.	No
14	Clear	No Data	No
15	Clear	Partially Clear	No
17	Clear	No Data	No

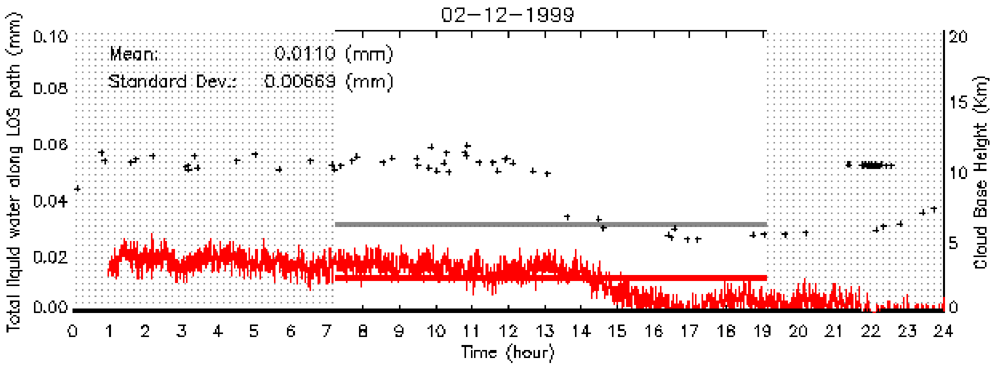
21	Clear	Partially Scattered	No
22	Clear	Mostly Scattered	No
23	Clear	No data	No

Month: August

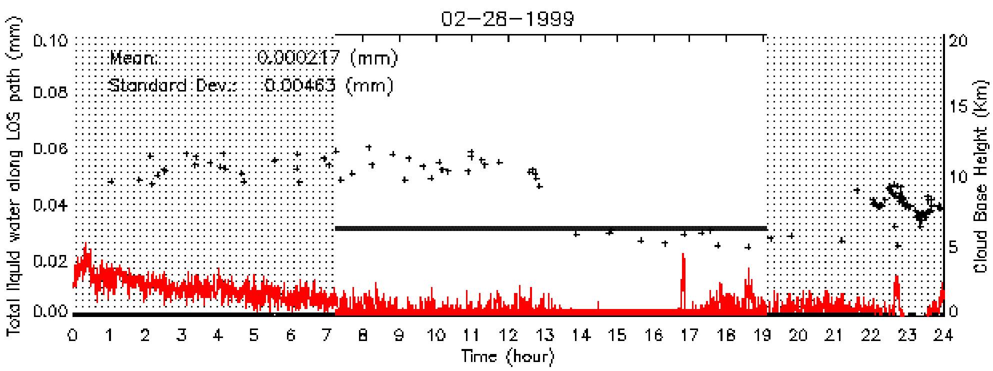
Day	MWR+MPL	Observation	Pristine ?
11	Clear	Scattered	No
13	Clear	Partially Scattered	No
14	Clear	Partially Clear	No
15	Clear	No Data	No
16	Clear	Partially Scattered	No
17	Clear	All clear but at 3 p.m.	Yes!
18	Clear	All clear but at 3 p.m.	Yes!
19	Clear	Mostly Scattered	No
20	Clear	Mostly Scattered	No
22	Clear	Scattered	No
23	Clear	All clear but at 12 a.m.	Yes!
24	Clear	Mostly Clear	Yes!
25	Clear	OK	Yes!
29	Clear	Scattered	No

Lastly, the next four plots---two wintertime and two summertime---illustrate either completely pristine days, or parts of pristine days. The tables below each plot provide hourly means and standard deviations of the measured liquid water paths in millimeters. Negative means are indications of retrieval uncertainty, resulting from regressing to a mean, and are within the noise limits of the MWR.

Winter pristine days:

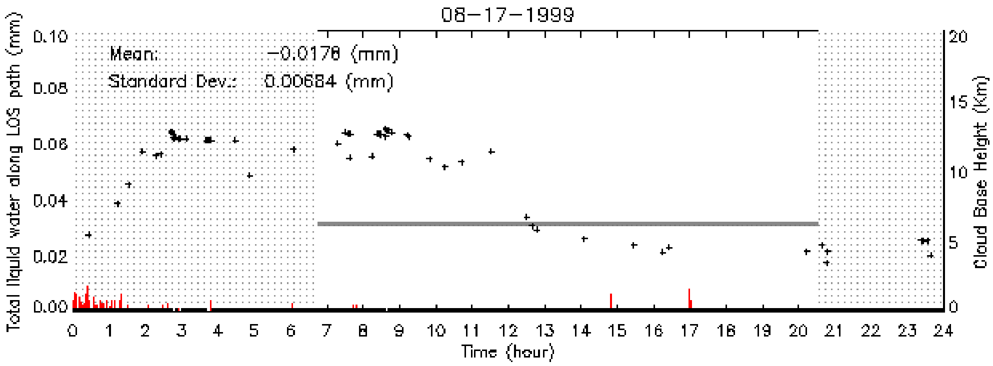


Hour	Mean	St. Dev.	Hour	Mean	St. Dev.	Hour	Mean	St. Dev.
1	0.013	0.0	9	0.016	0.0029	17	0.0017	0.0027
2	0.018	0.0034	10	0.017	0.0027	18	0.0018	0.0044
3	0.018	0.0032	11	0.015	0.0027	19	0.0044	0.0030
4	0.018	0.0028	12	0.013	0.0031	20	0.0028	0.0029
5	0.018	0.0027	13	0.015	0.0029	21	0.0032	0.0028
6	0.017	0.0027	14	0.015	0.0026	22	0.0017	0.0029
7	0.015	0.0029	15	0.010	0.0035	23	−0.0014	0.0026
8	0.016	0.0028	16	0.0049	0.0029	24	−0.0015	0.0027

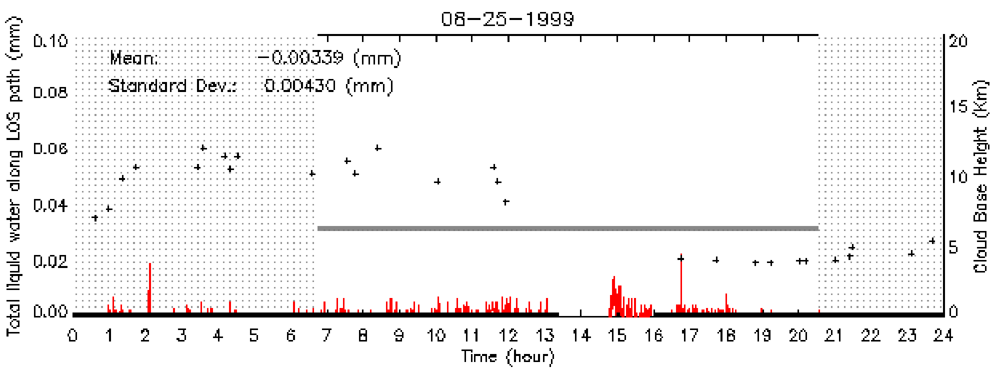


Hour	Mean	St. Dev.	Hour	Mean	St. Dev.	Hour	Mean	St. Dev.
1	0.015	0.0040	9	0.0026	0.0031	17	−0.0012	0.0059
2	0.012	0.0027	10	0.00086	0.0031	18	0.0019	0.0038
3	0.010	0.0024	11	0.00077	0.0026	19	0.0040	0.0040
4	0.0097	0.0024	12	0.0015	0.0027	20	0.0019	0.0030
5	0.0089	0.0027	13	0.0022	0.0027	21	0.0028	0.0027
6	0.0070	0.0025	14	−0.0013	0.0031	22	0.0017	0.0026
7	0.0062	0.0026	15	−0.0048	0.0030	23	−1.4	12.
8	0.0035	0.0027	16	−0.0066	0.0028	24	−0.033	0.068

Summer pristine days:



Hour	Mean	St. Dev.	Hour	Mean	St. Dev.	Hour	Mean	St. Dev.
1	−0.0015	0.0038	9	−0.011	0.0039	17	−0.018	0.0067
2	−0.0040	0.0036	10	−0.013	0.0035	18	−0.015	0.0055
3	−0.0053	0.0038	11	−0.014	0.0034	19	−0.021	0.0040
4	−0.0068	0.0034	12	−0.015	0.0034	20	−0.020	0.0044
5	−0.0090	0.0031	13	−0.021	0.0037	21	−0.024	0.0038
6	−0.0080	0.0033	14	−0.022	0.0034	22	−0.022	0.0037
7	−0.0068	0.0037	15	−0.023	0.0060	23	−0.022	0.0040
8	−0.0082	0.0041	16	−0.025	0.0038	24	−0.023	0.0030



Hour	Mean	St. Dev.	Hour	Mean	St. Dev.	Hour	Mean	St. Dev.
1	−0.010	0.0046	9	−0.0036	0.0041	17	−0.0027	0.0041
2	−0.0034	0.0036	10	−0.0030	0.0032	18	−0.0030	0.0041
3	−0.0053	0.0039	11	−0.0030	0.0035	19	−0.0044	0.0036
4	−0.0046	0.0037	12	−0.0015	0.0034	20	−0.0065	0.0037
5	−0.0059	0.0033	13	−0.0026	0.0035	21	−0.0093	0.0032
6	−0.0060	0.0035	14	−0.0053	0.0035	22	−0.010	0.0037
7	−0.0049	0.0036	15	0.0038	0.0044	23	−0.014	0.0038
8	−0.0031	0.0034	16	−0.0012	0.0044	24	−0.012	0.0036

Concluding Remarks

Recall that the identification of pristine days at ARM's Southern Great Plains site was one of several steps leading to our ultimate goal: the determination of whether SBDART, as a tool, was effective for estimating the red and blue background radiances at ANY site around the globe. Were we to proceed, our next step in this process would be to compare the radiances from the Whole Sky Imager on the days identified as being cloud-free against the corresponding estimates from SBDART. In all likelihood, the level of agreement between the two would diminish outwards from the zenith towards the horizon, regardless of season or time of day. A determination would have to be made as to whether the falloff in accuracy was within acceptable limits. If not, would the coding associated with a plane-parallel assumption have to be replaced with coding that portrayed the atmosphere as an arching layer? Furthermore, to establish once and for all that SBDART was, indeed, a site-independent tool, the foregoing analyses would have to be repeated at ARM's Tropical West Pacific and North Slope of Alaska sites.

References

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J.E. Shields, T.L. Koehler, M.E. Karr. & R.W. Johnson, 1990: Automated Cloud Cover and Visibility Systems for Real Time Applications. University of California, San Diego, Scripps Institution of Oceanography, Marine Physical Laboratory, Optical Systems Group Technical Note No. 217.

P. Ricchiazzi, S. Yang, C. Gautier & D. Sowle, 1998. SBDART: A Research and Teaching Software Tool for Plane-Parallel Radiative Transfer in the Earth's Atmosphere. Bullettin of the Amer. Meteor. Soc., Vol 79 No. 10.

Appendix

Program list:

```
        pro pristine

;       Program for comparison of "Total liquid water along
;       LOS path" from MWR and of "Cloud base height" from MPL
;       data files versus time

;       create framework for color plotting...wait to use
        DEVICE, pseudo = 8
        red   = [1,0,1,0,0,1]
        green = [1,0,0,1,0,1]
        blue  = [1,0,0,0,1,0]
        TVLCT, 255*red, 255*green, 255*blue
        TVLCT, R, G, B, /get
         !P.Multi = [0,1,2]

         ;open files containing MPL and MWR file names
         month = 'febr' ;month analyzed
         mt = '02'
         nm_mpl = strarr(31)
         openr, 20, 'list_mpl_'+month+'.txt'
         readf, 20, nm_mpl
         close, 20
         nm_mwr = strarr(31)
         openr, 21, 'list_mwr_'+month+'.txt'
         readf, 21, nm_mwr
         close, 21
```

```
    for iii = 21,31 do begin ; Main loop over the days of the month

         ; setting of the file name for the current day
         if iii lt 10 then begin
            day = string(format = '(I1)',iii)
            day ='0'+day
         endif else begin
            day = string(format = '(I2)',iii)
         endelse

         ; check if for the current day both the MWR and MPL files are available
         str_mwr = 'sgpmwrlosC1.b1.1999'+mt+day
         flag_mwr = 1
         ind_mwr = 0
         while (ind_mwr le 30) and (flag_mwr eq 1) do begin
               res_mwr = strpos(nm_mwr(ind_mwr),str_mwr)
               if res_mwr ne -1 then begin
                  flag_mwr =0
               endif else begin
                  ind_mwr = ind_mwr+1
               endelse
         end
         ; in the winter month the mpl file name strings are longer
         ;  by four character ("nor1")
         if ((mt ne 01) and (mt ne 02)) then begin
            st = ''
         endif else begin
            st = 'nor1'
         endelse
         str_mpl = 'sgpmpl'+st+'campC1.c1.1999'+mt+day
         flag_mpl = 1
         ind_mpl = 0
         while (ind_mpl le 30) and (flag_mpl eq 1) do begin
               res_mpl = strpos(nm_mpl(ind_mpl),str_mpl)
               if res_mpl ne -1 then begin
                  flag_mpl =0
               endif else begin
                  ind_mpl = ind_mpl+1
               endelse
         end
         flag_sum = flag_mwr+flag_mpl
         ; if  one file is not available this day is skipped
         if (flag_sum gt 0) then begin
            goto, JUMP
         endif


;        Open and read NetCDF files

; ---    storage of the year, month and day relative to MWR data
         name_mwr = '../input/mwr/'+month+'/'+nm_mwr(ind_mwr)
         year = strmid(name_mwr,33,4)
         mm = strmid(name_mwr,37,2)
         dd = strmid(name_mwr,39,2)
         hours = float(strmid(name_mwr,42,2))
         min = float(strmid(name_mwr,44,2))
         sec = float(strmid(name_mwr,46,2))
         shift = 3600*hours+60*min+sec
         tl = mm+'-'+dd+'-'+year
        cdfid_in_mwr = ncdf_open(name_mwr, /NOWRITE)
        if cdfid_in_mwr eq -1 then message, 'cannot open file'
         print, name_mwr

;        read array dimension

         dimension_id = ncdf_dimid(cdfid_in_mwr, 'time')
         if dimension_id eq -1 then message, $
                 'unable to get dimension in mwr file'
         ncdf_diminq, cdfid_in_mwr, dimension_id, time, size

;        read time_offset

        time_offset_id = ncdf_varid(cdfid_in_mwr, 'time_offset')
        if time_offset_id eq -1 then message, $
                'unable to get time_offset in mwr file'
                ncdf_varget, cdfid_in_mwr, time_offset_id, time_offset
         time_offset = time_offset+shift
```

```
;       read liq

        liq_id = ncdf_varid(cdfid_in_mwr, 'liq')
        if liq_id eq -1 then message, $
                'unable to get liq in mwr file'
                ncdf_varget, cdfid_in_mwr, liq_id, liq
        liq = liq*10

;       ***********************************************************

; ---   storage of time shift for MPL data

        name_mpl = '../input/mpl/'+month+'/'+nm_mpl(ind_mpl)
        ; in the winter month the mpl file name strings are longer
        ;  by four character ("nor1")
        if ((mt ne 01) and (mt ne 02)) then begin
           h = 0
        endif else begin
           h = 4
        endelse
        hours = float(strmid(name_mpl,43+h,2))
        min = float(strmid(name_mpl,45+h,2))
        sec = float(strmid(name_mpl,47+h,2))
        ;print, hours, min, sec
        shift = 3600*hours+60*min+sec

        cdfid_in_mpl = ncdf_open(name_mpl, /NOWRITE)
        if cdfid_in_mpl eq -1 then message, 'cannot open file'
        print, name_mpl

;       read array dimension

        dim_mpl_id = ncdf_dimid(cdfid_in_mpl, 'time')
        if dim_mpl_id eq -1 then message, $
                'unable to get dimension in mpl file'
        ncdf_diminq, cdfid_in_mpl, dim_mpl_id, time, size_mpl

;       read time_offset

        time_offset_id_mpl = ncdf_varid(cdfid_in_mpl, 'time_offset')
        if time_offset_id_mpl eq -1 then message, $
                'unable to get time_offset in mpl file'
                ncdf_varget, cdfid_in_mpl, time_offset_id_mpl, time_offset_mpl
        time_offset_mpl = time_offset_mpl+shift


;       read cloud_base_height

        cbh_id = ncdf_varid(cdfid_in_mpl, 'cloud_base_height')
        if cbh_id eq -1 then message, $
                'unable to get cbh in mpl file'
                ncdf_varget, cdfid_in_mpl, cbh_id, cbh

;       ************************************************************

;       Set of thick marks (hours).

        !x.tickname = ['0', '1', '2', '3', '4', '5', '6', '7', '8', '9', $
        '10', '11', '12', '13', '14', '15', '16', '17', '18', '19', '20', $
        '21', '22', '23', '24']
        !x.ticks = 24
        !x.style = 1

;       Sunris (tmin) and sunset (tmax) time.

        if mm eq '01' then  begin
          tmin = 27120
          tmax = 62880
        endif
        if mm eq '02' then  begin
          tmin = 26100
          tmax = 68880
        endif
        if mm eq '06' then  begin
          tmin = 22260
          tmax = 75300
        endif
        if mm eq '07' then  begin
          tmin = 22740
```

```
          tmax = 75560
        endif
        if mm eq '08' then  begin
          tmin = 24240
          tmax = 73940
        endif
        if mm eq '09' then  begin
          tmin = 25680
          tmax = 70800
        endif

        ; cbh0 contains data referred to the first level
        cbh0 = fltarr(size_mpl)
        cbh0(0:(size_mpl-1)) = cbh(0,*)

;        Axes and labels plot.

         plot, /normal, /nodata, time_offset, liq, xrange=[0.0,86400.0], $
               yrange = [0,0.1], title = tl, xtitle = "Time (hour)", $
               ytitle = "Total liquid water along LOS path (mm)", $
               xmargin = [8, 8], ymargin = [4,4], color = 1

        ;note: 200 is the factor that allow to obtain a [0,20] range
        ;       starting from a [0,0.1] range.
         axis, 86400,0,0, yaxis = 1, yrange = !y.crange*200, $
               ystyle = 1, $
               ytitle = "Cloud Base Height (Km)", color = 1

;        Computation of mean and standard deviation for daylight data.

         sum = 0
         cont  = 0
         flag = 0
         for i = 0,size-1 do begin
             if(time_offset(i) ge tmin and time_offset(i) le tmax) then begin
               if(flag eq 0) then begin
                 first = i
                 flag = 1
               end
               sum = sum+liq(i)
               cont = cont+1
               last = i
             end
         end
         mean = sum/cont
         var = 0
         for i = first,last do begin
             var = var+(liq(i)-mean)*(liq(i)-mean)
         end
         var = var/(cont-1)
         sd = sqrt(var)

;        Check for liq maximum limit and plot a limit line.
;        Above that there is rain.

         minval = !y.crange[0]
         maxval = !y.crange[1]

;        Limit line of pristine day Liquid Water Content
          polyfill, [0, 86400,86400,0], [0.03, 0.03, 0.03+0.002, 0.03+0.002], $
                    col = 0.90*!d.n_colors

;        Filling with plots hours before sunrise.

         pat = bytarr(4,4)
         pat(2,2) = 255
         xx1 = [0, tmin, tmin, 0]
         yy1 = [minval, minval, maxval, maxval]
         ;polyfill, xx1, yy1, col = 0.90*!d.n_colors
         polyfill, xx1, yy1, pat = pat

;        Filling with plots hours after sunset.

         xx2 = [tmax, 86400, 86400, tmax]
         yy2 = [minval, minval, maxval, maxval]
         ;polyfill, xx2, yy2, col = 0.90*!d.n_colors
         polyfill, xx2, yy2, pat = pat

;        Plot of the total liquid water along LOS path versus time.
```

```
        oplot, time_offset, liq, color = 2

;       Plot of the total cloud base height versus time.

        ; cbh0/200 to obtain a properly scaled value of cloud base height
        ;  with the actual scale for it
        oplot, time_offset_mpl, cbh0/200, color = 1, psym = 1, symsize = 0.5

;       Plot of mean value line (if mean is positive)
        if mean gt 0 then begin
           xx3 = [tmin, tmax, tmax, tmin]
           yy3 = [mean, mean, mean+0.002, mean+0.002]
           polyfill, xx3, yy3, color = 2
        endif

;       Labels plot and positioning.

        str1 = 'Mean:         '+string(format = '(A10)', mean)+' (mm)'
        str2 = 'Standard Dev.:'+string(format = '(A10)', sd)+' (mm)'
        xyouts, 3600, 0.09, color = 1,$
                str1, charsize = 1.1, $
                charthick = 1.5
        ;d = (max(liq)-min(liq))/10
        d = 0.01
        xyouts, 3600, 0.09-d, str2, charsize = 1.1, color = 1,$
                charthick = 1.5


;       Computation of mean and standard deviation for each hour.

        sum = 0
        cont  = 0
        hr = 0
        i = 0
        i = long(i)
        hour = 3600
        hour = long(hour)
        meanh = fltarr(24)
        varh = fltarr(24)
        sdh = fltarr(24)
        flag1 = 0
        flag2 = 0
        while (i le (size-1)) and (hr le 23) do begin
              while ((time_offset(i) le hour) and (flag2 ne 1)) do begin
                    if flag1 eq 0  then begin
                       first = i
                       flag1 = 1
                    end
                    sum = sum+liq(i)
                    cont = cont+1
                    last = i
                    if (i lt size-1) then begin
                       i = i+1
                    endif else begin
                       flag2 = 1
                    endelse
              end
              if cont eq 0 then begin
                 meanh(hr) = 0
                 sdh(hr) = 0
              endif
              if cont eq 1 then begin
                 meanh(hr) = sum
                 sdh(hr) = 0
              endif
              if cont gt 1 then begin
                 meanh(hr) = sum/cont
                 var = 0
                 for i = first,last do begin
                     var = var+(liq(i)-meanh(hr))^2
                 end
                 varh(hr) = var/(cont-1)
                 sdh(hr) = sqrt(varh(hr))
              endif
              hr = hr+1
              flag1 = 0
              sum = 0
              cont = 0
```

```
              hour = hour+3600
              i = i+1
        end

;       Second plot: table with the mean and standard deviation for each hour.

        !x.tickname = [' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',$
                       ' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ']
        !y.tickname = [' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',$
                       ' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ',' ']
        plot, /nodata, time_offset, liq, xrange=[0.0,86400.0], $
              yrange=[0,0.1], ticklen = 0, $
              xmargin = [8, 8], ymargin = [4,4], color = 1
        start = !x.crange(0)+1800
        height = !y.crange(1)-d
        sh = 7200
        str3 = 'Hour'
        str4 = 'Mean'
        str5 = 'St. Dev.'
        xyouts, start, height, str3, charsize = 1.2, charthick = 1.5, $
                color = 1
        xyouts, start+sh+900, height, str4, charsize = 1.2, charthick = 1.5, $
                color = 1
        xyouts, start+2.5*sh, height, str5, charsize = 1.2, charthick = 1.5, $
                color = 1
        xyouts, start+30000, height, str3, charsize = 1.2, charthick = 1.5, $
                color = 1
        xyouts, start+30000+sh+900, height, str4, charsize = 1.2,  $
                charthick = 1.5, color = 1
        xyouts, start+30000+2.5*sh, height, str5, charsize = 1.2, $
                charthick = 1.5, color = 1
        xyouts, start+58000, height, str3, charsize = 1.2, charthick = 1.5, $
                color = 1
        xyouts, start+58000+sh+900, height, str4, charsize = 1.2, $
                charthick = 1.5, color = 1
        xyouts, start+58000+2.5*sh, height, str5, charsize = 1.2, $
                charthick = 1.5, color = 1
        str = [start, start+30000, start+58000]
        for ii=1,3 do begin
          ind = (ii-1)*8
          start = str(ii-1)
          for i=ind,ind+7 do begin
             str6 = string(format = '(I3)', i+1)
             str7 = strcompress(string(format = '(A9)', meanh(i)))
             str8 = strcompress(string(format = '(A9)', sdh(i)))
             xyouts, start, height-d*(i+1-ind), $
                     str6, charsize = 1.2, charthick = 1.5, color = 1
             xyouts, start+sh, height-d*(i+1-ind), $
                     str7, charsize = 1.2, charthick = 1.5, color = 1
             xyouts, start+2.5*sh, height-d*(i+1-ind), $
                     str8, charsize = 1.2, charthick = 1.5, color = 1
          end
        end

        ncdf_close, cdfid_in_mwr
        ncdf_close, cdfid_in_mpl

        JUMP: ;Label to skip those days without both (MWR and MPL) files
        stop
    end ; End of main loop over the days

end
```