1. Main Data Specs

The matchup data collect data from three data sources: CloudSat 2B-GEOPROF, CloudSat ECMWF-AUX, and AMSU-B or MHS data from NOAA-##/METOP-A satellites. The provided data files are in HDF4 format. The scientific data (SD) fields of interest in this product follow:

<table>
<thead>
<tr>
<th>Data</th>
<th>Data Type</th>
<th>Data Origin</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPR Time</td>
<td>FLOAT32</td>
<td>CS GEOPROF (Profile_time)</td>
<td>Seconds since 00Z 01/01/2006</td>
</tr>
<tr>
<td>CPR Latitude</td>
<td>FLOAT32</td>
<td>CS GEOPROF (Latitude)</td>
<td>Degrees (-90 to +90)</td>
</tr>
<tr>
<td>CPR Longitude</td>
<td>FLOAT32</td>
<td>CS GEOPROF (Longitude)</td>
<td>Degrees (-180 to +180)</td>
</tr>
<tr>
<td>CPR Surface Bin</td>
<td>INT8</td>
<td>CS GEOPROF (SurfaceHeightBin)</td>
<td></td>
</tr>
<tr>
<td>CPR Surface Elevation</td>
<td>INT16</td>
<td>CS GEOPROF (DEM elevation)</td>
<td>meters</td>
</tr>
<tr>
<td>CPR Height</td>
<td>INT16</td>
<td>CS GEOPROF (Height)</td>
<td>m</td>
</tr>
<tr>
<td>CPR Reflectivity</td>
<td>INT16</td>
<td>CS GEOPROF (Radar Reflectivity)</td>
<td>dBZe</td>
</tr>
<tr>
<td>EC 2m Temperature</td>
<td>FLOAT32</td>
<td>CS ECMWF-AUX (Temperature_2m)</td>
<td>K</td>
</tr>
<tr>
<td>EC 2m Pressure</td>
<td>FLOAT32</td>
<td>CS ECMWF-AUX (Surface_pressure)</td>
<td>Pa</td>
</tr>
<tr>
<td>EC Skin Temperature</td>
<td>FLOAT32</td>
<td>CS ECMWF-AUX (Skin temperature)</td>
<td>K</td>
</tr>
<tr>
<td>EC Temperature</td>
<td>FLOAT32</td>
<td>CS ECMWF-AUX (Temperature)</td>
<td>K</td>
</tr>
<tr>
<td>EC Pressure</td>
<td>FLOAT32</td>
<td>CS ECMWF-AUX (Pressure)</td>
<td>Pa</td>
</tr>
<tr>
<td>EC Specific Humidity</td>
<td>FLOAT32</td>
<td>CS ECMWF-AUX (Specific humidity)</td>
<td>kg/kg</td>
</tr>
<tr>
<td>BH Time</td>
<td>FLOAT32</td>
<td>NOAA CLASS</td>
<td>Seconds since 00Z 01/01/2006</td>
</tr>
<tr>
<td>BH Latitude</td>
<td>FLOAT32</td>
<td>NOAA CLASS</td>
<td>Degrees (-90 to +90)</td>
</tr>
<tr>
<td>BH Longitude</td>
<td>FLOAT32</td>
<td>NOAA CLASS</td>
<td>Degrees (-180 to +180)</td>
</tr>
<tr>
<td>BH Surface Index</td>
<td>INT8</td>
<td>NOAA CLASS</td>
<td>0=ocean, 1=land, 2=coast</td>
</tr>
<tr>
<td>BH Beam Position</td>
<td>INT8</td>
<td>NOAA CLASS</td>
<td>(0 to 89)</td>
</tr>
<tr>
<td>BH Satellite ID</td>
<td>CHAR8</td>
<td>NOAA CLASS</td>
<td>K,L,M,N,P,2</td>
</tr>
<tr>
<td>BH Brightness Temperature</td>
<td>INT16</td>
<td>NOAA CLASS</td>
<td>K</td>
</tr>
</tbody>
</table>

A sample header of one of the files is listed below (generated from “ncdump -h”):

```plaintext
netcdf 2009002111311_14273_CS_2B-GEOPROF_AMSUB-MHS_R04_E02 {
  dimensions:
    N_CPR_BEAMS = 37082 ;
    N_CPR_BINS = 125 ;
    TWO_PIXELS = 2 ;
    FIVE_TBS = 5 ;
  variables:
    float CPR_TIME(N_CPR_BEAMS) ;
      CPR_TIME:CPR_TIME_ATTR = "Seconds counting from 00Z Jan. 1, 2006 " ;
    float CPR_LATITUDE(N_CPR_BEAMS) ;
    float CPR_LONGITUDE(N_CPR_BEAMS) ;
    byte CPR_SURFACE_BIN(N_CPR_BEAMS) ;
    short CPR_SURFACE_ELEVATION(N_CPR_BEAMS) ;
    short CPR_HEIGHT(N_CPR_BEAMS, N_CPR_BINS) ;
    short CPR_REFLECTIVITY(N_CPR_BEAMS, N_CPR_BINS) ;
      CPR_REFLECTIVITY:Reflectivity_Attribute = "dBZe with scaling_factor and offset."
      Actual_dBZe=(dBZe-offset)/factor ;
      CPR_REFLECTIVITY:Scaling_Factor = 100.f ;
      CPR_REFLECTIVITY:Offset = 0.f ;
    float EC_2m_TEMPERATURE(N_CPR_BEAMS) ;
      EC_2m_TEMPERATURE:EC_2m_TEMP_Attribute = "Air Temperature in K at 2 meter above surface" ;
    float EC_2m_PRESSURE(N_CPR_BEAMS) ;
      EC_2m_PRESSURE:EC_2m_P_Attribute = "Pressure at surface in Pa " ;
    float EC_SKIN_TEMPERATURE(N_CPR_BEAMS) ;
  }
```
2. CloudSat Data

The Cloud Profiling Radar (CPR) is a 94-GHz nadir-looking radar which measures the power backscattered by clouds as a function of distance from the radar. The minimum detectable reflectivity factor requirement is ~ -26 dBZ\(^1\). CPR data in this product are extracted from CloudSat 2B-GEOPROF product (ver.4), which has radar reflectivity values in 150 bins in the vertical with a bin size of about 240 m. The footprint size of the radar reflectivity profiles is 1.4 km (cross track) and 2.5 km (along track).

3. ECMWF Data

Collocated ECMWF data are also included in this product, which are extracted from ECMWF-AUX data.

4. AMSU-B & MHS Data

AMSU-B is a cross-track, line scanned instrument designed to measure scene radiances in 5 channels at frequencies of 89, 150, 183\(\pm1\), 183\(\pm3\), and 183\(\pm7\) GHz. It is on board NOAA-15, -16, and -17 satellites. At each channel frequency, the antenna beamwidth is a constant 1.1 degrees (at the half power point). Ninety contiguous scene resolution cells are sampled in a continuous fashion, each scan covering 50 degrees on each side of the subsatellite path. These scan patterns and geometric resolution translate to a 16.3 km diameter cell at nadir at a nominal altitude of 850 km.

\(^1\) http://cloudsat.atmos.colostate.edu/instrument
All antenna beams for AMSU-B scan in a plane perpendicular to the instrument's baseplate, containing nadir in the x-z plane. The maximum deviation from the scan plane will be less than or equal to 0.1 degrees. The direction of scan motion is from sun (+z) to nadir (+x) to antisun side (-z). During earth scan, the cross track motion will be continuous with the angular velocity constant to within ±2%. All antenna beams will scan ±48.95 degrees about nadir with reference to the beam axis. The scan period will be 8/3 seconds, in order to maintain a relationship with the AMSU-A scan pattern.²

MHS is a revised version of AMSU-B, has a slightly different operating frequencies: 89, 157, 183±1, 183±3, and 190 GHz. In addition, its polarization is also slightly different from that of AMSU-B. For AMSU-B, all channels are vertically-polarized at nadir, while for MHS, 89, 157 and 190 GHz are vertically-polarized at nadir, and the 183±1 and 183±3 channels are horizontally-polarized at nadir.

AMSU-B/MHS data are downloaded from NOAA CLASS data archival system (http://www.class.ncdc.noaa.gov/saa/products/welcome)

3. File Name Description
Now, simply replace “ECMWF-AUX” by “AMSUB-B_MHS” in the ECMWF-AUX file name. To be modified later.

4. Intersect Selection Method
For this project, an intersect will be defined as both CloudSat radar and the radiometers on the grouping of NOAA-15, 16, 17, 18, 19, and METOP-A satellites observing the nearly same geographic location on the planet at nearly same time. The criteria for the collocation is set the centers between CloudSat and AMSU-B/MHS pixels is less than 25 km apart, and the time difference between the two observations are less than 15 minutes. The distance between the two pixel centers are computed by latitude/longitude on a spherical coordinate assuming the Earth is a sphere with radius of 6371 km. The time difference itself is approximately 15 minutes within a radius of around 25 km.

From all AMSU-B/MHS pixels that meet the above criteria, two pixels are selected and saved in the HDF file; the first according to shortest spatial distance and the second according to shortest time difference. In many instances, the two pixels are actually the same pixel.

5. An example
The following figures show a Jan 2, 2009 case (CloudSat Granule 14274). Figure 1 is the quick-look image; the granule starts at 12:52:04 UTC and has a length of ~ 100 min. Figure 2 shows the CPR reflectivity and matched brightness temperatures at a function time (in min.).

Figure 1  CloudSat orbits and quick-look image for Granule 14274.

Figure 2. CPR matched with AMSU-B/MHS brightness temperatures.
6. Sample Read Program (downloadable from web)

6.1 Fortran:  The following fortran 90 program reads a HDF file and print out parts of the data:

Program read_merged.cloudsat_ams
!
! G. Liu  S/24/2010
! compile with: gfortran -I$(HDFHOME)/include -L$(HDFHOME)/lib \
! rdcldsatmhs.f90 -o whatever -lmfhdf -ldf -ljpeg -lz
!
! implicit none
integer (kind=4), parameter :: DFACC_READ=1
character (len=150) :: filename
integer (kind=4), parameter :: NBIN=125,NPIX=2,NCH=5,MAXBEAM=40000
integer (kind=4) :: nbeam,i,j,k
real (kind=4) :: ctime(MAXBEAM),clat(MAXBEAM),clon(MAXBEAM), &
alat(NPIX,MAXBEAM),alon(NPIX,MAXBEAM),atime(NPIX,MAXBEAM), &
t2m(MAXBEAM),p2m(MAXBEAM),tskin(MAXBEAM),p(NBIN,MAXBEAM), &
t(NBIN,MAXBEAM),sh(NBIN,MAXBEAM)
integer (kind=2) :: height(NBIN,MAXBEAM),dbz(NPIX,NCH,MAXBEAM), &
elev(MAXBEAM),tbs(NPIX,NCH,MAXBEAM)
integer (kind=1) :: csurfb(MAXBEAM),asurfinx(NPIX,MAXBEAM), &
apos(NPIX,MAXBEAM)
character (len=1) :: satid(NPIX,MAXBEAM)
real (kind=4) :: cfactor,afactor
!
! character (len=64) :: wk
integer (kind=4) :: sfstart,sfselect,sfrdata,sfendacc,sfend,sffattr, &
sfrattr,sfn2index
integer (kind=4) :: sd_id,sds_id,sds_index,status,attr_inx
integer (kind=4) :: start(3),edges(3)
!
call getarg(1,filename)
if(filename.eq."" .or. filename.eq."-h" .or. filename.eq."--help") then
print*, "Usage: rdcldsatmhs file_name"
stop
endif

sd_ids=sfstart(filename,DFACC_READ)
!
! find how many collocated pixels
wk="N CPR BEAMS"
attr_inx=sffattr(sd_id,wk)
status=sfrattr(sd_id,attr_inx,nbeam)
!
print*, nbeam,"matches in ",filename
!
start[1]=0
start[2]=0
start[3]=0
!
stride[1]=1
stride[2]=1
stride[3]=1
!
!
read CPR time
wk="CPR TIME"
sds_index=sfn2index(sd_id,wk)
eds=0
!
read CPR LAT & LON
wk="CPR LATITUDE"
sds_index=sfn2index(sd_id,wk)
eds=0
!
read CPR SURFACE BIN NUMBER
wk="CPR SURFACE BIN"
sds_index=sfn2index(sd_id,wk)
eds=0
!
read CPR SURFACE ELEVATION
wk="CPR SURFACE ELEVATION"
sds_index=sfn2index(sd_id,wk)
eds=0
! read ECMWF 2m T & P, skin temp
wk="EC_2m_TEMPERATURE"
sds_index=sfn2index(sd_id,wk)
sds_id=sfselect(sd_id,sds_index)
edges(1)=nbeam
status=sfrdata(sds_id,start,stride,edges,EC_2m_TEMPERATURE)
sds_index=sfn2index(sd_id,wk)
sds_id=sfselect(sd_id,sds_index)
edges(1)=nbeam
status=sfrdata(sds_id,start,stride,edges,EC_2m_PRESSURE)
sds_index=sfn2index(sd_id,wk)
sds_id=sfselect(sd_id,sds_index)
edges(1)=nbeam
status=sfrdata(sds_id,start,stride,edges,EC_SKIN_TEMPERATURE)
wk="EC_2m_PRESSURE"
status=sfrendacc(sds_id)
wk="EC_SKIN_TEMPERATURE"
status=sfrendacc(sds_id)

! read CPR HEIGHT
wk="CPR_HEIGHT"
sds_index=sfn2index(sd_id,wk)
sds_id=sfselect(sd_id,sds_index)
edges(1)=NBIN
edges(2)=nbeam
status=sfrdata(sds_id,start,stride,edges,CPR_HEIGHT)
status=sfrendacc(sds_id)

! read CPR reflectivity
wk="CPR_REFLECTIVITY"
sds_index=sfn2index(sd_id,wk)
sds_id=sfselect(sd_id,sds_index)
edges(1)=NBIN
edges(2)=nbeam
status=sfrdata(sds_id,start,stride,edges,CPR_REFLECTIVITY)
wk="Scaling Factor"
attr_inx=sffattr(sds_id,attr_inx,cfactor)
status=sfrattr(sds_id,attr_inx,cfactor)
status=sfrendacc(sds_id)

! read ECMWF T, P, S.Hum profile
wk="EC_TEMPERATURE"
sds_index=sfn2index(sd_id,wk)
sds_id=sfselect(sd_id,sds_index)
edges(1)=NBIN
edges(2)=nbeam
status=sfrdata(sds_id,start,stride,edges,EC_TEMPERATURE)
wk="EC_pressure"
sds_index=sfn2index(sd_id,wk)
sds_id=sfselect(sd_id,sds_index)
edges(1)=NBIN
edges(2)=nbeam
status=sfrdata(sds_id,start,stride,edges,EC_pressure)
wk="EC_SPECIFIC_HUMIDITY"
sds_index=sfn2index(sd_id,wk)
sds_id=sfselect(sd_id,sds_index)
edges(1)=NBIN
edges(2)=nbeam
status=sfrdata(sds_id,start,stride,edges,EC_SPECIFIC_HUMIDITY)

! read AMSU-B/MHS time, latitude & longitude
wk="BH_TIME"
sds_index=sfn2index(sd_id,wk)
sds_id=sfselect(sd_id,sds_index)
edges(1)=NPIX
edges(2)=nbeam
status=sfrdata(sds_id,start,stride,edges,BH_TIME)
wk="BH_LATITUDE"
sds_index=sfn2index(sd_id,wk)
sds_id=sfselect(sd_id,sds_index)
edges(1)=NPIX
edges(2)=nbeam
status=sfrdata(sds_id,start,stride,edges,BH_LATITUDE)
wk="BH_LONGITUDE"
sds_index=sfn2index(sd_id,wk)
sds_id=sfselect(sd_id,sds_index)
edges(1)=NPIX
edges(2)=nbeam
status=sfrdata(sds_id,start,stride,edges,BH_LONGITUDE)

! read AMSU-B/MHS pixel surface index
wk="BH_SURFACE_INDEX"
sds_index=sfn2index(sd_id,wk)
sds_id=sfselect(sd_id,sds_index)
edges(1)=NPIX
edges(2)=nbeam
status=sfrdata(sds_id,start,stride,edges,BH_SURFACE_INDEX)
status=sfrendacc(sds_id)

! read AMSU-B/MHS pixel scanning position
wk="BH_BEAM_POSITION"
## 6.1 matlab

A matlab (rd_AMSUB_CLDSAT_matlab.m) contributed by Ben Johnson at NASA/GSFC is also downloadable from the web. It assumes the pdf file name to be “a.pdf” and read the following parameters into memory:

- CPR_TIME
- CPR_LATITUDE
- CPR_LONGITUDE
- CPR_SURFACE_BIN
- CPR_SURFACE_ELEVATION
- CPR_HEIGHT
- CPR_REFLECTIVITY
- EC_2m_TEMP
- EC_2m_PRESSURE
- EC_SKIN_TEMP
- EC_TEMP
- EC_pressure
- EC_SPECIFIC_HUMIDITY
- BH_TIME
- BH_LATITUDE
- BH_LONGITUDE
- BH_SURFACE_INDEX
- BH_BEAM_POSITION
- BH_SATELLITE_ID
- BH_TB