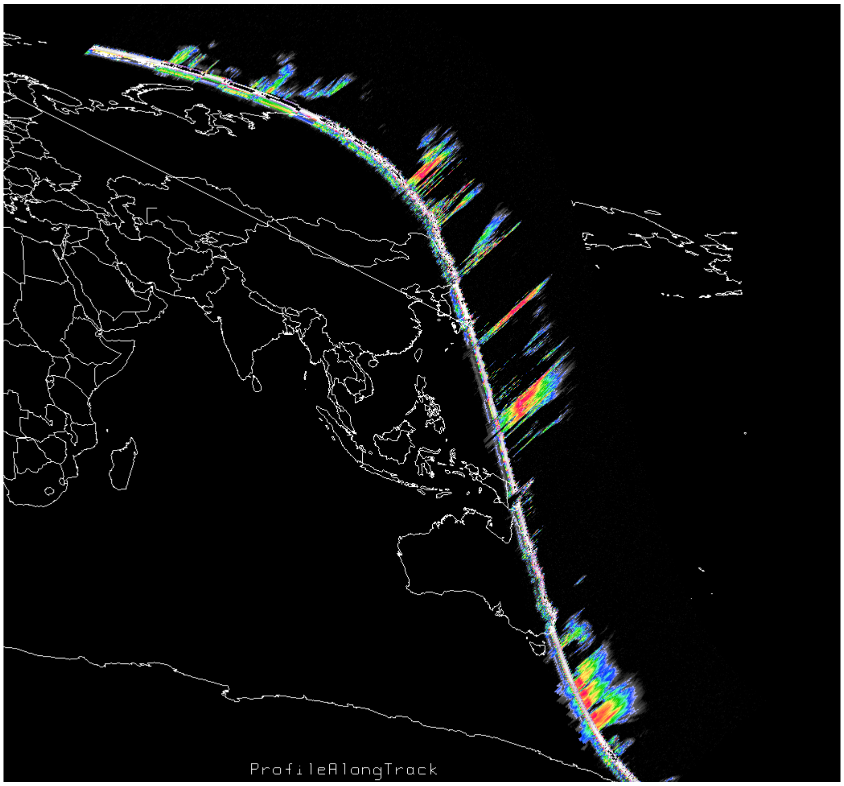
LAB - Combining IR+VIS+MW with CloudSat space-borne radar

We will look at a case from August 2006 in which there are various types of precipitation present in the same scene, and we will explore this using multiple sensors (AMSR-E and MODIS which we have used already, and CloudSat, a space-borne cloud radar) to better understand the advantages and disadvantages of each instrument.

Instructions for this lab (key questions are in yellow):

1. Open McIDAS-V
2. Add MODIS data:
    a. Go to **Data Sources** tab in the **Data Explorer** window
    b. Click the arrow next to **Satellite** and select **Imagery**
    c. **Server**: <LOCAL-DATA>
    d. **Dataset**: “MODIS”
    e. **Click Connect**
    f. **Image Type**: “Level 1 B Data”
    g. Go to the **Absolute** tab and select the image at **2006-08-09 04:15:00 UTC**
    h. Click **Add Source**
    i. Now you can plot MODIS channels similarly to how you plotted AMSR-E channels in the earlier lab. (Remember to click the “Divergent Green Arrows” if you want full resolution images).
    j. Plot at least one visible and one infrared channel.
3. Now plot some AMSR channels:
    a. Add a local ADDE dataset in Mcidas-V:
        i. In the map window select **Tools → Manage ADDE Datasets**
        ii. Select **Add New Dataset** and fill in the required information
        iii. **Dataset**: “AMSR”
        iv. **Image Type**: “AMSR”
        v. **Format**: “AMSR-E L 1b”
        vi. **Directory**: point to the **Data → AMSR** directory
        vii. Click **Add Dataset** and **OK**
    b. Add this as data source
        i. Go to **Data Sources** tab in the **Data Explorer** window
        ii. Click the arrow next to **Satellite** and select **Imagery**
        iii. **Server**: <LOCAL-DATA>
        iv. **Dataset**: “AMSR”
        v. Click **Connect**
        vi. **Image Type**: “AMSR”
        vii. Go to the **Absolute** tab and select the image at **2006-08-09 03:47:12 UTC**
        viii. Click **Add Source**
    c. Now you can plot any microwave channels, with the same steps you used in the microwave lab.
4. Plot CloudSat
    a. Go to **Data Sources** tab in the **Data Explorer** window
    b. Click the arrow next to **General** and select **Files/Directories**
    c. Navigate to the file ‘**2006221032546_01497_CS_2B-GEOPROF_GRANULE_P_R04_E01.hdf**’ in the folders **Data → Cloudsat**
    d. Select ‘HYDRA data source’ under **Data Type**
    e. Click **Add Source**
    f. In the **Field Selector** tab, select the filename under the **Data Sources** panel
    g. In the Fields panel, select **ProfileAlongTrack → 2B-GEOPROF/Data_Fields/Radar_Reflectivity**
    h. **Select ProfileAlongTrack Display** in the **Displays** panel
    i. In the **Track** tab, change both **Track stride** and **Vertical stride** to **1**

j. Hold **Shift + left-click + drag** to draw a green box around the portion of the orbit from Russia to Antarctica
k. Click **Create Display**
l. This is the first time we have plotted data that utilizes the 3-dimensional capabilities of McIDAS-V. You can use **Ctrl + right-click** to rotate the display. You will need to rotate the display to see the vertical cross section of radar reflectivity from CloudSat such as in the image below.



m. On the left side of your map window, you will see six cubes. If you get disoriented, you can always click the topmost of these cubes to reset to a top-down viewpoint.
n. Note: the horizontal white lines on the CloudSat display represent height levels of 2km, 7km and 12km.
o. Take a minute to look at the CloudSat observations. Feel free to ask us if you if you are confused about what you are looking at.

5. You now have coincident MODIS, AMSR, and CloudSat observations. Feel free to explore the scene as you wish, but here are several science questions you could consider:
   a. CloudSat
      i. Classify the different types of precipitation you see. (Is it convective or stratiform? What are the cloud top heights? Is the precipitation at the ground frozen or liquid?)
      ii. What is happening to the CloudSat profile over New Guinea?
      iii. Focusing on frontal system south of Australia:
         1. Can you identify areas of vertical transition from snow to liquid? Which type of precipitation is associated with higher reflectivities?
      iv. Focusing on tropical convection in the Pacific Ocean
         1. Inspect the vertical reflectivity structure of the tropical convection. Why do you think the reflectivity becomes small in the lowest few km?
   b. AMSR
      i. For the tropical convection in the Pacific Ocean, look at 89GHz-V brightness temperatures. Some areas of precipitation are associated with enhanced brightness temps, some with low brightness temps (compared to the "background" ocean surface). What do you think is causing this difference? (The 36 GHz channel may be helpful here as well)

   ii. Look at the 6 GHz channel for the different types of precipitation. How transparent is the atmosphere at this channel for each type of precipitation?

c. MODIS
   i. Inspect the tropical convection with MODIS. This is a good illustration of the advantages of CloudSat over IR imagery – with IR imagery, it can be difficult to determine the location of convective precipitation cores due to cirrus cloud cover, but with CloudSat we can see the vertical structure!

6. Finally… Make your own rain rate retrieval!
   a. (Note: This part requires two or three calculations. If you don't have a calculator at hand, we can help you).
   b. Create an AMSR polarization difference image: 18.7V – 18.7H
      i. In the **Data Explorer** window, select the **Field Selector** tab
      ii. Select **Formulas** under the **Data Sources** panel
      iii. Under the **Fields** panel, select **Miscellaneous** → **Simple difference a-b**
      iv. Select **Imagery** → **Image Display** in the **Displays** panel
      v. Click **Create Display**
      vi. Select the **Temperature** for the appropriate channels under **AMSR**
      vii. Click **Create Display**
   c. Zoom in on deep convective region north of New Guinea
   d. Find the ocean area NEAR the rainfall that has HIGHEST polarization difference (use the middle mouse button).
   e. Write down the value you found for maximum polarization difference. Lets call it X. This should be just one number.
   f. By creating a new formula, make the following plot: (19V-19H)/X .
      i. In the map window, click **Tools** → **Formulas** → **Create Formula**
      ii. Name the formula "Transmittance"
      iii. Type in the formula: **(V19-H19)/X** (where X is your polarization difference)
      iv. Click **Add Formula**
      v. Open the **Field selector** tab in the **Data Explorer** window
      vi. Select **Formulas** in the **Data Sources panel**
      vii. Find your formula (named "Transmittance") under **SEVIRI Differences** in the **Fields** panel
      viii. Select **Imagery** → **Image Display** in the **Displays** panel
      ix. Click **Create Display** and select the appropriate AMSR fields in the pop-up window
      x. Change the data range for this image to 0 to 1. This is a proxy for atmospheric transmittance. Note, transmittance is less than 1 in areas of precipitation.
   g. Similarly to the previous step, create another formula and plot it: **-10.0*log((v19-h19)/X)**
      i. This is a proxy for rain rate.
   h. Determine the maximum rain rate in your plot and write it down. Let's call it RMAX.
   i. Using a calculator, estimate the corresponding radar reflectivity using this relationship: **Z=200*RMAX^1.6**
   j. Using a calculator, take the value from the previous step and convert it to logarithmic units: **dBZ=10.0*log10(Z)**
   k. Compare your dBZ value to CloudSat radar reflectivities. Do you see radar reflectivities that high? Is it reasonable?