# JPSS Operational Satellite Data Integration and Collocation algorithms development and Evaluation


Haibing Sun[1], Walter Wolf[2], Thomas King[1] Shanna Sampson [1]

NOAA Satellite and Information Services
National Environmental Satellite, Data, and Information Service

[1] I.M. System Group, 3206 Tower Oaks Boulevard, Suite 300,Rockville, MD 20852 [2] NOAA/NESDIS/STAR, 5830 University Research Ct, NCWCP , College Park, MD 20740



## SUMMARY:

Instrument physical based collocation algorithms are developed at NOAA/NESDIS/STAR to support the development of the satellite observation integration processing. Those algorithms are applied within the Geostationary satellite & Polar satellite (GEO-LEO) integration system and LEO-LEO observation operational integration system. The Cross-track Infrared Sounder (CrIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS) are two key instruments on board S-NPP/JPSS for imaging the Earth's weather, climate, and environment and are used for a wide range of applications related to atmosphere, oceans, land, and hazards. The sensor data and cloud products on the VIIRS pixels are collocated to the CrIS fields of view (FOV) with a Lookup Table (LUT) based fast collocation algorithm. These collocated VIIRS/CrIS data provide extended spectral and spatial resolution to CrIS product processing. This fast collocation system currently runs operationally in NESDIS within the NOAA Unique Combined Atmospheric Processing System (NUCAPS) package and provides VIIRS content to the CrIS BUFR product. In this paper, the detail of the updated LUT algorithm are introduced and problems in the collocation processing and the related solutions are discussed.


## METHODOLOGY

The LUT based physical collocation processing includes two steps: 1: Off-line collocation LUT calculation; 2:Install the LUT for real time collocation processing.

1: Off-line collocation LUT calculation:

CrIS/VIIRS collocation LUT is built for CrIS scan line. Within the LUT, The CrIS/VIIRS match-up information for each CrIS fields of view is included in a two dimension array which give the relative scan line index, FOV index, relative distance and contribution weight of the collocated VIIRS FOVs. There are totally 270 arrays in the LUT. The relative scan line index is defined as the scan line index difference between the collocated VIIRS scan line index and collocated VIIRS base line index. The match-up information in collocation LUT is defined by the CrIS-VIIRS observation relative position. The satellite observation position on the ground is defined by line-of-sight vectors (LOS) on Spacecraft Body Frame(SBF) and satellite platform Ephemeris. The match-up information is retrieval with the normal collocation processing( Haibing 2005). The real CrIS/VIIRS geo-location data used to retrieve the match-up information work as a training dataset. With the assumption that the "fixed" relative position between the collocation processing candidate, The off-line trained LUT can be used for later collocation/Integration processing.

Install the LUT for real time collocation processing.

The installation of the LUT in collocation processing include steps:

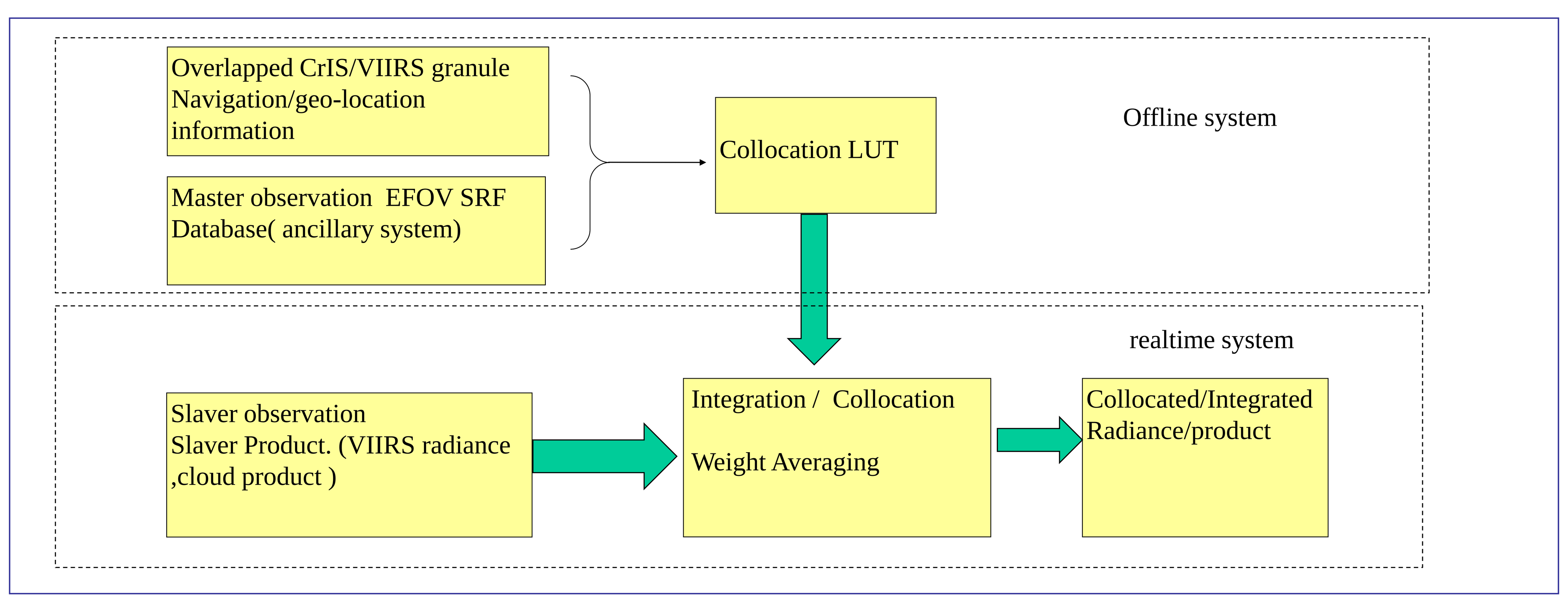
1: Build spatial overlapped CrIS and VIIRS granule file dataset.

2: For the CrIS line for collocation processing, search the collocated VIIRS base line index $b_i$ with scanning middle time .

3: Loop over CrIS FOV (1-30), For each CrIS FOV, get the relative scan index $r_i$ , FOV index $f_i$, distance from the CrIS center, Contribution weight $w_i$ from the LUT. The collocated VIIRS are defined by scan line index $S_i$ and FOV index $f_i$ , and $S_i = b_i + r_i$.

4: Basing on the collocated VIIRS observation, Integration the collocated VIIRS observation/Product and clustering analyzing .

## Data Flow





haibing.sun@noaa.gov


## Collocation LUT & Master Observation EFOV SRF

The match-up information in collocation LUT is defined by the CrIS-VIIRS observation relative position and CrIS effective field of view (EFOV) spatial response function (SRF) . The observed radiance is contributed by all the points within the EFOV. The EFOV is defined as effective area swept by the sensor observation beam during the integration time. The physical collocation required the collocated observation and physical variables have the same spatial and physical representivity. The collocation LUT include geo-location match-up and EFOV SRF information. The collocation LUT is trained with offline physical collocation. At present training, a simple CrIS EFOV SRF model from the instrument requirement is used (Figure 1.0). In the training, the satellite position is the interpolation result of orbit equation, the bias angle between the master FOV LOS vector (from Master satellite position to master FOV on surface) and all collocated slaver FOV LOS(from Master satellite position to slaver FOV on surface) are calculated basing CrIS/VIIRS geo-location information. The contribution weight of surroundings slaver FOV is calculated basing on the bias angle and the master EFOV SRF model. This contribution weight is used to identify the collocated VIIRS and get the collocated VIIRS position indexs for LUT, the contribution weight is also saved in LUT for radiance weigh averaging.

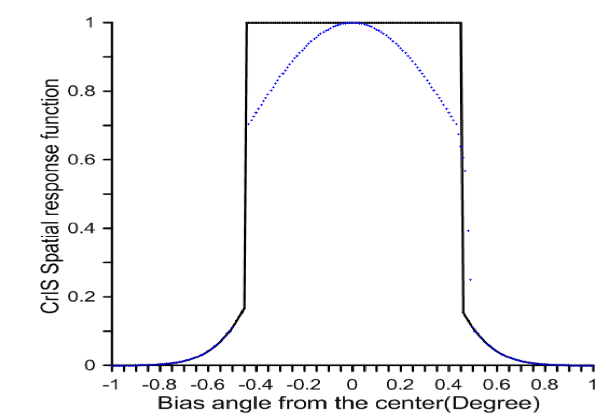



Figure 1.0 EFOV SRF model

**Problem in the LUT Method:** The LUT collocation method require that the relative position between the collocation observation from different observation system keep "Fixed", then a pre-calculated LUT for the collocation can be used in the real time processing. The satellite observation position on the ground is defined by line-of-sight vectors (LOS) and satellite platform ephemeris. The satellite Ephemeris is the function of time. Given two LOS of satellite observation are fixed, the relative earth position is function of the satellite ephemeris difference and thus the function of observation time difference. The CrIS scan mirror stepwise "stares " at the Earth step by step in the cross-track direction from 48.3° to +48.3 with a 3.3° step angle and takes 8s for each scan sweep. VIIRS apply the Rotating Telescope Assembly (RTA) along with the rotating HAM to produces the VIIRS cross-track scanning and scan interval is 1.784 second. CrIS/VIIRS scanning units rotate with two different periods and there is no synchronization between CrIS and VIIRS scanning. The observation time difference is not fixed.

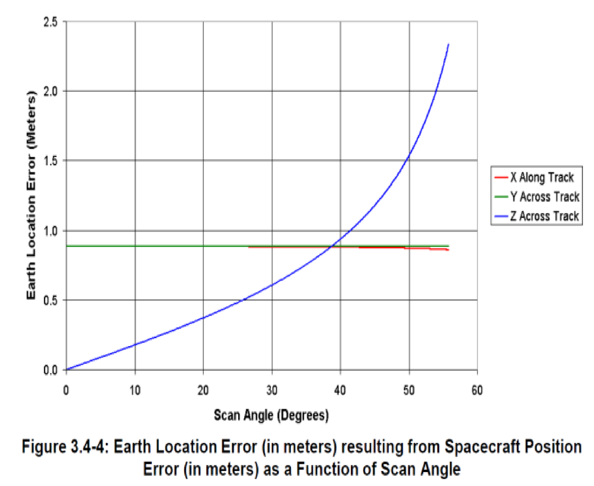



Figure 2 (From VIIRS Geo ATBD).

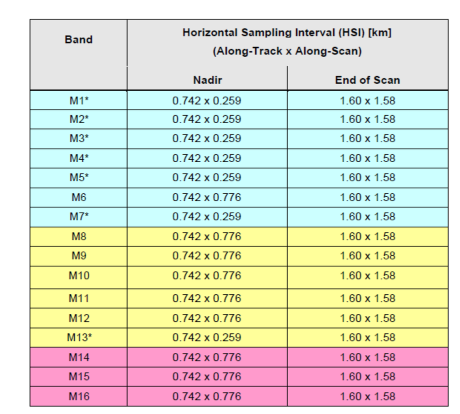


Figure 3:VIIRS spatial resolution

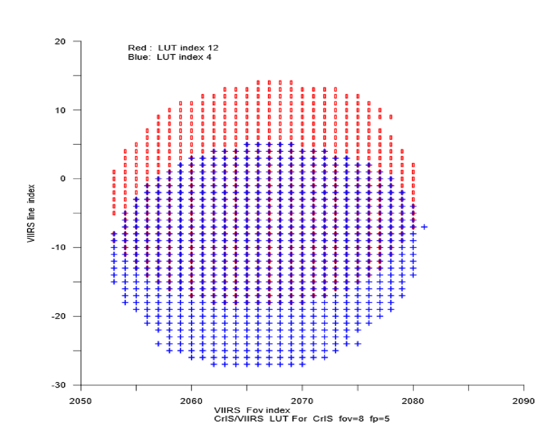


Figure 4 LUT FOV 8th

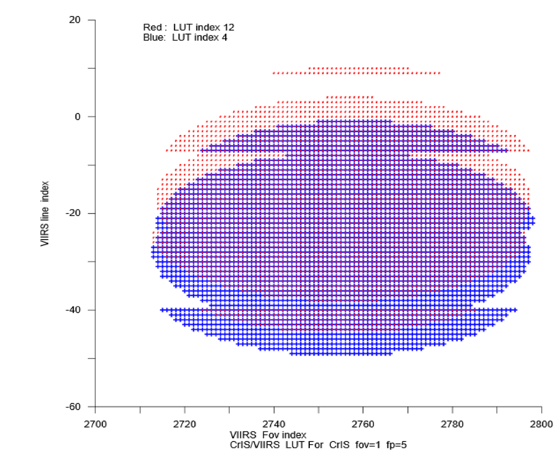


Figure 5: LUT FOV 1st

Basing on the VIIRS spatial resolution and the relative position variation *vs* satellite position changing(Figure 2,3), In collocation LUT training , the LUTs are trained at 16 even distributed time point within [0,1,784]. The time intervals is 0.113 second and the surface along track movement is about 0.75km. This is the spatial resolution of the collocation LUT. This solution is comparable with the VIIRS "M" band SDR data spatial resolution in the nadir and better than VIIRS SDR spatial resolution in the scan edge. (Figure 4,5)

**The relative position variation relating with satellite attitude :** CrIS/VIIRS relative position is effected by satellite attitude. Spacecraft with momentum actuators suffer from attitude jitter and high frequency oscillations due to imbalance in the rotors of momentum actuators. Beside the attitude jitter, NPP satellite attitude also has the system variance pattern according to the latitude(Figure 7,8). Figure 6 give the earth surface displacement from the satellite pointing /attitude error.

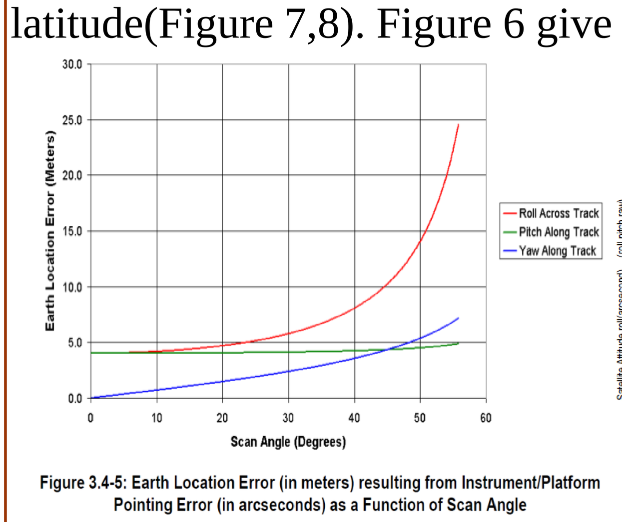



Figure 6 (From VIIRS Geo ATBD)

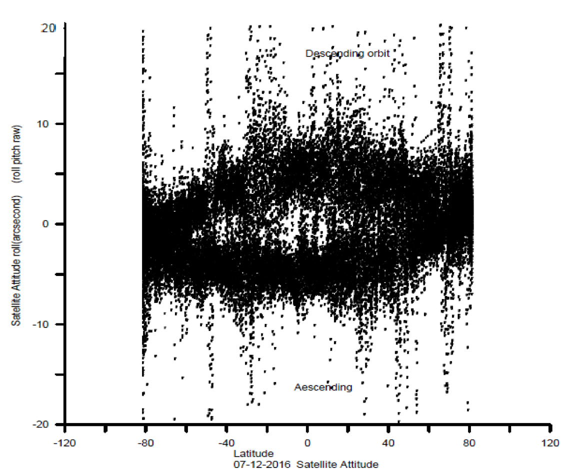


Figure 7: Satellite attitude: Roll

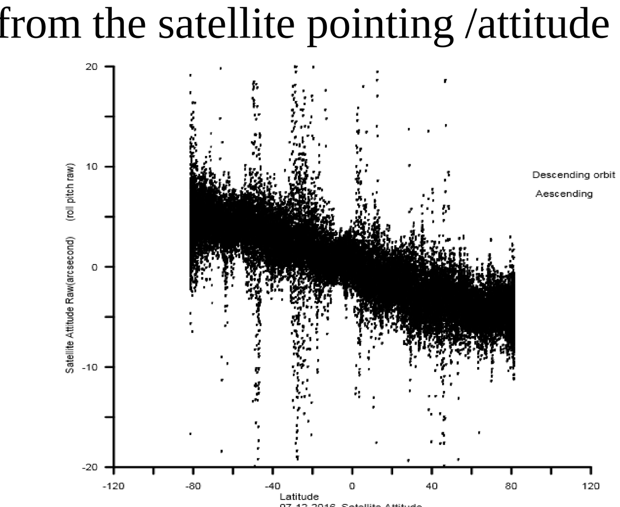


Figure 8: Satellite attitude: Raw

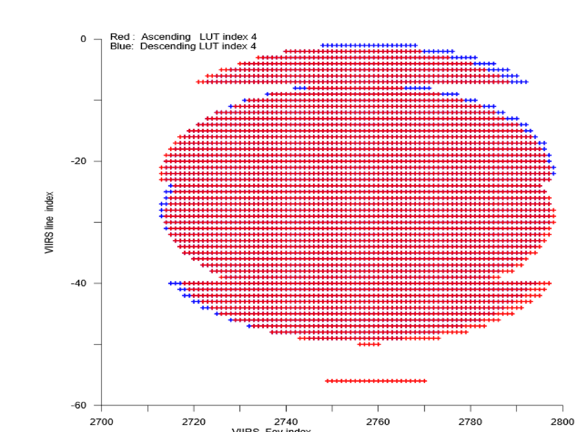


Figure 9: LUT Descending/Ascending

There exist some noticed effect from the satellite attitude for the collocated VIIRS position index ( $r_i$ , $f_i$ ) pattern(Figure 9). In present LUT training, the collocation LUT are trained for ascending and descend observation independently with descending and ascend data from the equator area.

**VIIRS Bowie Effect:** VIIRS "bow tie " leads to scan-to-scan overlap at big scan angles. VIIRS ground processing aggregate the VIIRS observation in the along-track direction and trims the data to exclude some of the samples in the overlap area, But the scan to scan overlap still exist in the large scan angle area and lead to the un-uniformly VIIRS sampling distribution.(Figure 10) To avoid problem introduced from the un-even slaver observation sampling problem, a two dimension grid G(X,Y) defined with scan angle bias (Figure 11) is used to selected the qualified slaver observation from the spatial overlapped VIIRS FOV in LUT Training.

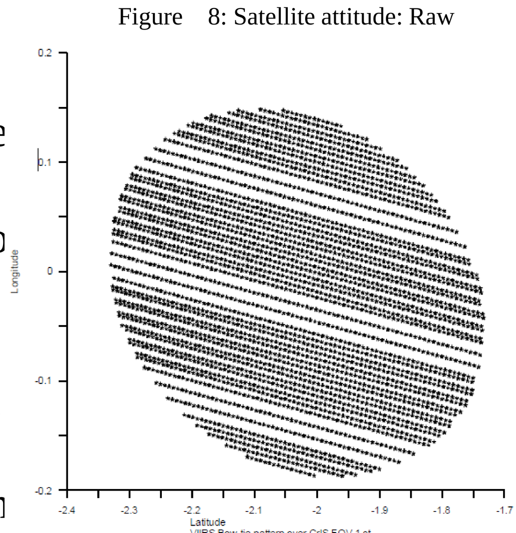


Figure 10: Bow tie within CrIS FOV

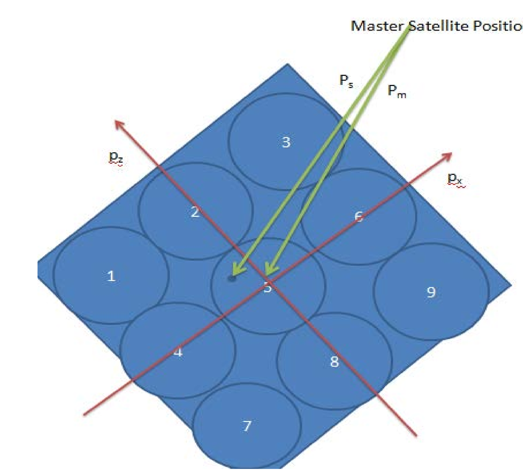



Figure 11: Grid definition

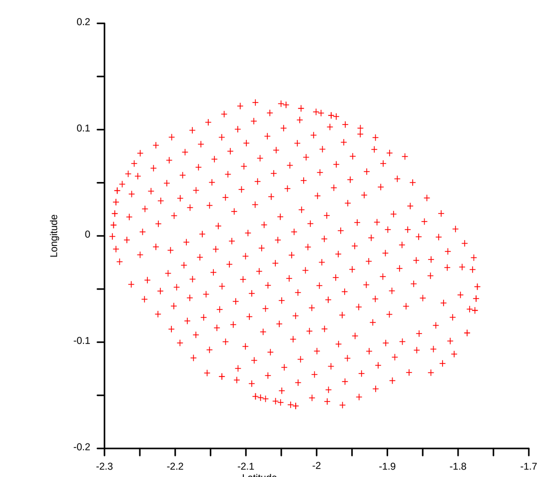
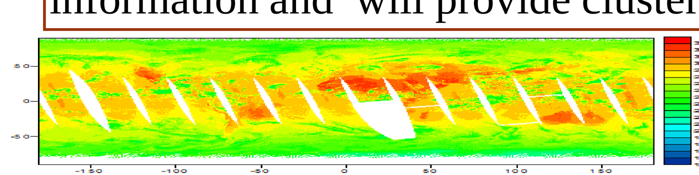
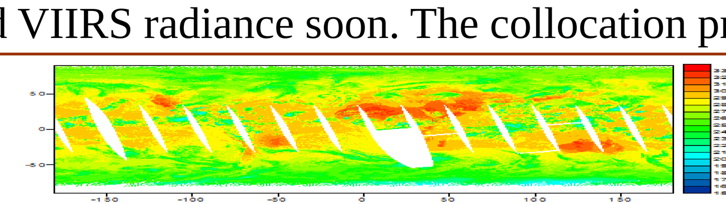


Figure 12: Gridded LUT

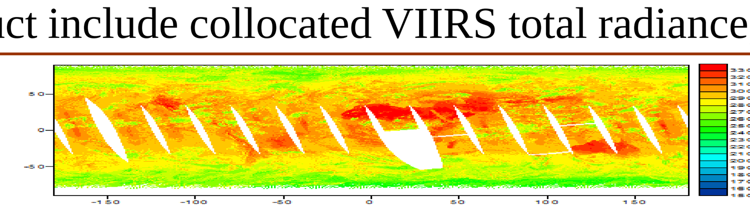
**Conclusion:** Two steps validations are performed: The validation of LUT based algorithms *vs* the searching based method; The validation of the physical collocation algorithm with the comparison between the spatial collocated VIIRS radiance and the spectral convoluted CrIS radiance. JPSS Integration Processing system provide sub-pixel collocated VIIRS radiance , cloud information and will provide clustered VIIRS radiance soon. The collocation product include collocated VIIRS total radiance, cloud/clear radiance, cloud fraction and cloud height.



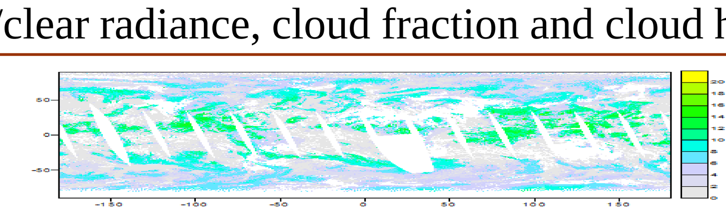
Collocated VIIRS M13 BT 09/12/2014



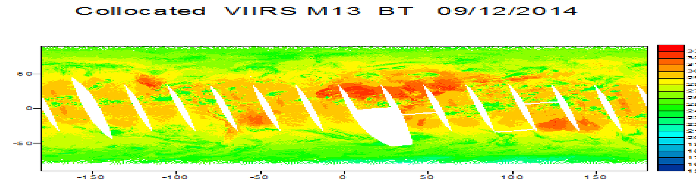
Collocated VIIRS M15 BT 09/12/2014



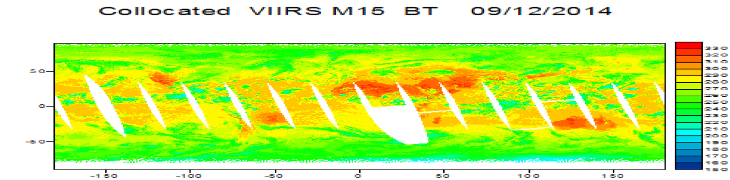
Collocated VIIRS M12 BT 09/12/2014



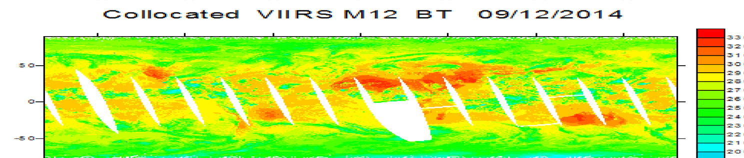
Collocated VIIRS Average Cloud Height 09/12/2014



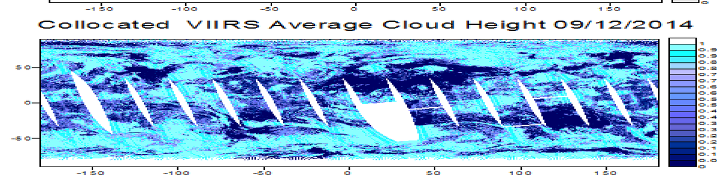
Spectral Convoluated CrIS M13 BT 09/12/2014



Spectral convoluated CrIS M15 BT 09/12/2014



Collocated VIIRS M16 BT 09/12/2014



Collocated VIIRS Cloud fraction 09/12/2014