JPSS Operational Satellite Data Integration and Collocation algorithms development and Evaluation

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

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GAMA-1 TECHNOLOGIES

SUMMARY:

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. On board S-NPP/JPSS, the Cross-track Infrared Sounder (CrIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS) are two key instruments 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 observed radiance data and cloud products on the VIIRS pixels are collocated to the CrIS fields of view (FOV) with a Lookup Table (LUT) method basing on the fast collocation algorithm. These collocated VIIRS/CrIS data provide extended spectral and spatial resolution to CrIS product processing. This collocation system currently runs operationally in NESDIS within the NOAA Unique Combined Atmospheric Processing System (NUCAPS) package provides collocated VIIRS cloud content to the CrIS BUFR product. In this paper, the detail of the present LUT algorithm are introduced and problems in the collocation processing and the related solutions are discussed.

METHODOLOGY

The LUT based physical collocation: Off-line LUT Training; Real time collocation processing with LUT

Off-line LUT Training: LUT is built for the CrIS scan line. Within the LUT, The CrIS/VIIRS match-up information for each CrIS fields of view(30x 9) is included in a two dimension array which give the relative line index, FOV index, relative distance and contribution weight of the collocated VIIRS FOVs. There are totally 270 two dimension arrays in the LUT. The relative line index is defined as the line index difference between the collocated VIIRS scan line index and collocated VIIRS base scan line index. The collocated VIIRS base scan line index is defined as the VIIRS scan line index with the closest scan line middle time. The match-up information in collocation LUT is defined by the CrIS-VIIRS observation relative position and CrIS spatial response function(SRF) of effective field of view(EFOV). 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 retrieved 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. The LUT need be updated periodically to accommodate the satellite ephemeris variance.

Real time collocation processing with LUT: The collocation processing steps:

- Build spatial overlapped CrIS and VIIRS granule file pair dataset.
- Determine the collocated VIIRS base scan line index b_i with CrIS&VIIRS scanning line middle time
- For each CrIS FOV(1-270), 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 $S_i = b_i + r_{i.}$
- Integration the collocated VIIRS observation/Product and clustering analyzing .

Collocation LUT & Master Observation EFOV SRF

The physical collocation required the collocated observation and physical variables have the same spatial and physical representivity. 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 EFOV is defined as effective area swept by the sensor observation beam during the integration time. The collocation LUT include both geo-location match-up and EFOV SRF information. The LUT used for operational collocation is trained with offline physical collocation processing. In the offline physical collocation processing, a simple CrIS EFOV SRF model from the instrument requirement is used (Figure 1.0). In the training, the satellite position is retrievaled from 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 in LUT, the contribution weight is also saved in LUT for collocation Integration.

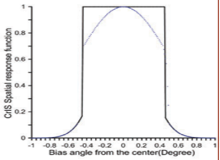

Figure 1.0 EFOV SRF model

The CrIS scan mirror stepwise "stares " at the Earth in the cross-track direction, The scan mirror slightly moves backward in the track direction, the FOV footprint on the Earth surface is frozen during the sampling time. The observation EFOV spatial response function can be represent instrument spatial response function

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LUT Method Update:

The LUT collocation method require that the relative position between the collocation observations 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 ground is defined by line-of-sight vectors (LOS) and satellite platform ephemeris (satellite position and attitude). 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 takes 8s for each scan sweep and VIIRS scan interval is 1.784 second. There is no synchronization between CrIS and VIIRS scanning and the observation time difference between CrIS scan line and collocated VIIRS scan line is not fixed. The middle scanning time difference between CrIS and collocated VIIRS base scan line collocated VIIRS base scan line ranges from 0 to 1.7864 seconds. Within this time range, The satellite position along track movement will be 0-13.2km. The corresponding observation displacement on ground range from 0-11.683 km. In CrIS/VIIRS collocation, To keep a "fixed" relative position, 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 and this solution is comparable with the VIIRS "M" band SDR data spatial resolution in the nadir. Fig 4, Fig 5 give the collocated VIIRS index in LUT with scanning time difference 0.452 sec and 1.356 at different FOV.

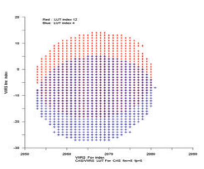

Figure 2: LUT: VIIRS index

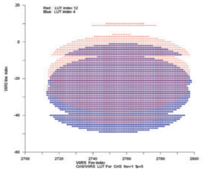

Figure 3: LUT : VIIRS index

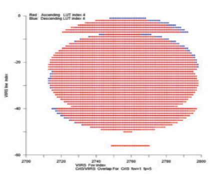

Figure 4 LUT :VIIRS index

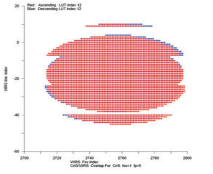

Figure 5: LUT at different satellite attitude

LUT update with satellite attitude : CrIS/VIIRS are onboard the same platform so with the same satellite attitude (If omit the high frequency variance). The relative position relating with scanning line time difference will be effected by the satellite attitude**.** Spacecraft with momentum actuators suffer from attitude jitter and high frequency oscillations due to imbalance in the rotors of momentum actuators, but those high frequency variance can not covered in present processing. JPSS/NPP satellite attitude also has the system variance pattern according to the latitude and those pattern are ascending/descending depended. To avoid the bias from system satellite attitude variance, In present LUT training, the collocation LUT are trained for ascending and descend observation independently with descending and ascend data from the equator area. Fig 4,5. Those LUTs will be used according to orbit type.

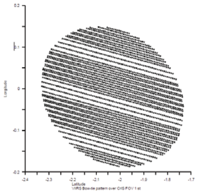

Figure 6 (LUT for Bowie effect

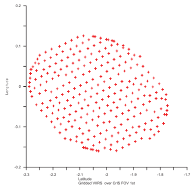

Figure 7: LUT for Bowie effect

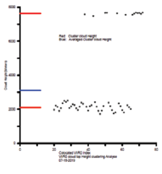

Figure 8: Cloud Top Height Clustering

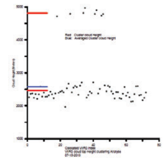

Figure 9:Cloud Height clustering

LUT update for 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.(Fig 6) To avoid problem introduced from the un-even slaver observation sampling problem, a two dimension grid G(X,Y) defined with scan angle bias (Fig 7) is used to selected the qualified slaver observation from the spatial overlapped VIIRS FOV in LUT Training.

LUT Installation Update :

The Physical collocation processing includes two step processing: observation collocation and observation regulation. Observation collocation processing is to search/identify slaver satellite observations /products that are spatially collocated, temporally concurrent and geometrically aligned to master observation. The LUT method are applied in the present collocation processing. Regulation processing regulate the collocated observations/products to the same physical represented subject:

$$\boldsymbol{obp_m} = \sum_{k=0}^{n} \boldsymbol{obp_s}\, \mathrm{w_k} \,/\, \sum_{k=0}^{n} \mathrm{w_k} \qquad 1.0$$

The $\boldsymbol{obp_m}$ is the regulated master (CrIS) observation/Product. $\boldsymbol{obp_s}$ is the slaver observation/Product (VIIRS). w_k is contribution weight. In the radiance collocation, The contribution weight w_k from LUT is applied directly in collocation and regulation . In the present cloud product collocation, w_k from LUT is used in collocated slaver observation(VIIRS) identification, the w_k or equal weight w are to be used to in regulation. The present CrIS/VIIRS collocation BUFR format output include the CrIS cloud fraction result with equal weight ($w_k = \mathbf{1}$) for all collocated VIIRS points and with definition : $\boldsymbol{obp_s}$ =0 at VIIRS clear& possible clear point, $\boldsymbol{obp_s}$ =1 at VIIRS cloud& possible clout point. The CrIS/VIIRS collocated cloud fraction, cloud top height, cloud top temperature et al products regulated with w_k are available on requirement. The clustering algorithms basing on the K-means clustering method is developed in collocated processing. For collocated radiance analyzing, the clustering is performed with radiance of all the available VIIRS channels. The clustering algorithms is also applied in collocated CrIS/VIIRS cloud top height collocation processing. The present CrIS/VIIRS collocation BUFR output include the CrIS/VIIRS cloud top height result with equal weight ($w_k = \mathbf{1}$) for all collocated VIIRS point and with definition: $\boldsymbol{obp_s}$ =0 at VIIRS clear& possible clear point, $\boldsymbol{obp_s}$ = the clustered cloud top height the VIIRS cloudy point belong at VIIRS cloudy& possible cloudy points. At the present processing, There is a option to choose the dominant up layer cloud top height or total layers averaging. Figure 8,9.

Conclusion: JPSS CrIS/VIIRS Integration Processing system provide collocated VIIRS radiance , cloud information and clustered VIIRS radiance product. The present operation collocation product include collocated VIIRS cloud fraction, cloud top height. The collocated total radiance, cloud/clear radiance, and other clustering product are available for user on requirement.