AMV FROM FENGYUN DUAL-GEO. STERE WITCH VIEW – SIMULATION AND BIAS ANALYSIS

Feng Lu, Yixuan Shou, Jianmin Xu

Office of System Development, National Satellite Meteorological Center, Beijing, 100081, China

Abstract

Before year 2020, over 5 FengYun Geosynchronous satellites will be launched, the satellite Sub Satellite Point (SSP) varied from 79°E to 133°E. Based on dual-GEO, stereo view of two FengYun Geosynchronous satellites, the Cloud Top Height (CTH) could be derived, and be applied for AMV retrievals.

In this paper, the optimal FengYun satellite pair for dual-GEO. stereo view and the AMV bias will be discussed.

1. INTRODUCTION

“Parallax is the apparent displacement, or difference in the apparent position of an object, caused by actual change (or difference) of observation point positions. The angular amount of such displacement or difference of position, being the angle contained between the two straight lines drawn to the object from the two different points of view, and constituting a measure of the distance of the object.” [1]

From year 2000, parallax technique has been applied on the atmospheric motion vectors (AMVs) retrieval based on the observation of Multi-angle Imaging Instrument boarding on the Leop-orbit satellite, MISR (Multi-angle Imaging Spectro Radiometer) on the Terra satellite for example. [2] While so far it has not been widely applied on the AMV retrieval based on GEO. satellites observations.

For Geo orbit AMV retrieval, one of the challenges is to precisely assign the cloud top height (CTH). In 1980s, Prof. Fujita first brought up the concept of stereographic CTH which based on a simplified equation [3] (shown as formula 1). In 1990s, Hasler give the idea of automatic stereoscopic height assignment on the basis of Prof. Fujita's concept [4] (Fig. 1)

\[ H = \frac{P}{P_{10}} \times 10Km \] ..............................(1)

H denotes CTH, \( P_{10} \) represents parallax when CTH is 10Km; \( P \) represents parallax offset observed in image pair.

Fig.1 Diagram of dual-GEO. CTH assignment [4]
From then on, many attempts are applied to dual-GEO. CTH assignment, GOES and Meteosat for example. Wylie and Santek attempts to derive visible channel CTH from Goes-8/9\(^5\); Campbell and Holmlund attempts to derive infrared channel CTH from Meteosat\(^6\); Lu and Xu attempt to derive CTH (both visible and infrared channel) from GOES10/11. The validation shows, with the good image navigation & registration(INR) and dual-GEO. observation time synchronous, the CTH assignment accuracy could be 500 meters\(^7\).

![Fig.2 CTH from dual-GEO. stereo view from GOES-10/11](image)

Nevertheless, there are some limitations in dual-GEO. CTH assignment. One of the biggest problems is that the two Geo satellites could not always keep time synchronous. The cloud movement between two satellites view is the big error source of CTH assignment. Therefore, this limitation could be the main reason that hampers the dual-GEO. CTH to be put into operation.

The short hand of the dual-GEO. CTH became its advantage. AMV could use one GEO. Observation time series to provide good cloud movement information, it could help dual-GEO. CTH to eliminate the time asynchronous effects, while the dual-GEO. CTH could help to improve CTH height assignment accuracy in the AMV algorithm.
2. FENGYUN GEO. SATELLITE SETTINGS

According to the long time-term plan of CMA Meteorological satellite system, FY-2 and FY-4 are Chinese geosynchronous meteorological satellite Series. The Fengyun GEO, covering wide area over Asia-Pacific region. With the upgrade from FY-2 to FY-4, the observation capability of Chinese GEO keeps improving. The Fengyun GEO could support dual-GEO AMV retrieval in both orbital position (Fig 3) and Imaging spatial resolution (Fig 4).

**Fig. 3 Orbital positions for FengYun Geo.**

**Fig. 4 The Channel setting of FengYun GEO.**

<table>
<thead>
<tr>
<th>FY-2 VISSR</th>
<th>Channel</th>
<th>Band (μm)</th>
<th>Spatial Resolution (Km)</th>
<th>Detection Sensitivity</th>
<th>Main Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible</td>
<td>FY-2 C/D/E</td>
<td>0.45~0.49</td>
<td>0.55~0.9</td>
<td>0.56~0.75</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>FY-2 F/G/H</td>
<td>S/N≥</td>
<td>70(90%)</td>
<td>200(90%)</td>
<td></td>
</tr>
<tr>
<td>Mid-wave Infrared</td>
<td>0.55~0.75</td>
<td>5</td>
<td>NEA(≤0.7K)(300K)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Vapor</td>
<td>0.75~0.90</td>
<td>5</td>
<td>NEA(≤0.3K)(200K)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-wave Infrared</td>
<td>1.30~1.39</td>
<td>2</td>
<td>NEA(≤0.2K)(300K)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.58~1.64</td>
<td>2</td>
<td>NEA(≤0.2K)(300K)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.1~2.35</td>
<td>2~4</td>
<td>NEA(≤0.2K)(300K)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FY-4A AGRI</th>
<th>Channel</th>
<th>Band (μm)</th>
<th>Spatial Resolution (Km)</th>
<th>Detection Sensitivity</th>
<th>Main Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible &amp; Near-Infrared</td>
<td>0.55~0.75</td>
<td>0.5~1</td>
<td>200(p=100%);5(p=1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>1</td>
<td>0.5Km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short-wave Infrared</td>
<td>1.30~1.39</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.58~1.64</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.1~2.35</td>
<td>2~4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-wave Infrared</td>
<td>3.5~4.0(high)</td>
<td>2</td>
<td>NEA(≤0.7K)(300K)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.5~4.0(low)</td>
<td>4</td>
<td>NEA(≤0.2K)(300K)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Vapor</td>
<td>5.8~6.7</td>
<td>4</td>
<td>NEA(≤0.3K)(200K)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.0~8.9</td>
<td>4</td>
<td>NEA(≤0.3K)(200K)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-wave Infrared</td>
<td>8.0~9.0</td>
<td>4</td>
<td>NEA(≤0.2K)(300K)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.3~11.3</td>
<td>4</td>
<td>NEA(≤0.2K)(300K)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.5~12.5</td>
<td>4</td>
<td>NEA(≤0.2K)(300K)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13.2~13.8</td>
<td>4</td>
<td>NEA(≤0.2K)(300K)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. **FENGYUN DUAL-GEO. AMV BIAS ANALYSIS**

FengYun GEO. have 7 orbital positions, in this study, we discuss two basic settings
1) Operational Setting(Fig 5) represent current FY-2 satellite constellation in 2014. Satellites are located at 86.5°E and 123.5°E
2) The potential Setting(Fig 5) represent the future possible setting of FY-2/4 with the biggest departure. Satellites are located at 79°E and 133°E.

The following discussions are based on these two settings.

![Operational Setting](image1)

**Operational Setting**

![Potential Setting](image2)

**Potential Setting**

**Fig. 5** FengYun dual-GEO. Overlaps

### 3.1 FY-2 DUAL-GEO. CTH -CAPABILITY

Before talking about the impact of FengYun dual-GEO. settings on AMV bias, we calculate the potential accuracy of CTH assignment on the basis of the two basic FengYun GEO. settings.First of all, we assume the satellites are in an ideal status meeting the following conditions:
1) with no image navigation registration bias;
2) two satellite make synchronous observation, make observation on the same location at the same time

![Meridional Slicing](image3)

**Operational Setting**

![Zonal Slicing](image4)

**Operational Setting**

<table>
<thead>
<tr>
<th>Operational Setting</th>
<th>Potential Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half FY-2 IR pixels</td>
<td>Half FY-2 IR pixels</td>
</tr>
<tr>
<td>Half FY-2 Vis pixel</td>
<td>Half FY-2 Vis pixel</td>
</tr>
</tbody>
</table>

**Fig. 6** Fengyun dual-GEO. Parallax Corresponding CTH
Fig. 6 shows the diagnose results. For the FengYun dual-GEO. Observations, a half of FY-2 IR pixel equals 2.5Km SSP resolution, and a half of FY-2 visible channel pixel equals 0.625Km SSP resolution. Assume the image offset bigger than a half pixel could be recognized by the image tracking algorithm, we could recognize CTH while its height is above 500 meters; for the potential setting, the lowest recognized CTH is about 400 meters.

Based on the above analysis, both the operational and potential settings could satisfy the AMV retrieval efficient height range.

### 3.2 FY-2 DUAL-GEO. AMV BIAS ANALYSIS

Few GEO. observation could be time synchronous. So in the real world, the apparent Image Pair Offset can be formulated as follows:

$$AO = O_{INR} + O_{parallax} + O_{cloudmotion} \ldots \ldots \ldots (2)$$

Here the AO is apparent image pair offset recognized between the dual-GEO. observations. $O_{INR}$ is the image pair offset by the Image navigation and registration error; $O_{parallax}$ is the dual-GEO. parallax effect itself related image pair offset, and the $O_{cloudmotion}$ is cloud movement during two satellites view time related image pair offset.

The Fig. 8 gives the schematic diagram of equation 2. T0 is the observation time of one satellite, and the $dT$ is the time different of two satellites looking at the same target.

Now, we move to the fundamental question of dual-GEO. AMV bias analysis.
1) How does INR bias effect CTH? Does it change with height?
2) How does cloud Motion effect on CTH? Is it a big error source?

For the first question, we can make a definition as:

$$dCTH = CTH_{\text{real}} - CTH$$

Here $CTH_{\text{real}}$ is CTH corresponding 1 pixel INR bias, 1 pixel equals 1.25Km in SSP.

Fig 9 gives the simulation result, we can see INR error related CTH varies less than 10 meters with height. So for the CTH assignment in AMV retrieval, this effect could be omitted. This finding is very useful for eliminate the INR error. Perhaps we could make CTH retrieval at first, then remove the INR error related CTH uncertainty, in this procedure, we can assume the INR's effect did not vary along the height for every specific locations.

To answer the second question, according to the observation of tropospheric wind speed over China in the past 50 years [8], we can suppose middle level(500hPa/5000m) zonal wind speed is 20m/s, and the high level(200hPa/12km) wind zonal speed is 80m/s. The FY-2 satellite makes full disk scan in 25 minutes, so we suppose the time difference of dual-GEO. view as 30 seconds. It is clear that the time asynchronous leads to cloud motion, during 30 seconds. The high level cloud moves 2400 meters eastward and the middle level cloud moves 600 meters eastward, such cloud motion leads to CTH error. As Fig 10 shown, 30 seconds of time asynchronous will lead to over 1Km CTH error for high level cloud.

Fig 10. dual-GEO. Time asynchronous effect on CTH (Operational Setting)
4. SUMMARY AND FUTURE WORK

According to the analysis above, the time asynchronous is the biggest error source for dual-GEO. AMV, INR bias effect on CTH could be considered constant for dual-GEO. AMV,Fig.11 gives the diagram of AMV retrieval under Dual-GEO.observation setting. We can use the iteration to eliminate wind height and wind speed uncertainties.

In the following 12 months, CMA plan to move FY-2F to 123.5°E in Q3,2014 for Rapid Scan service. By then, combining FY-2(86.5°E) with FY-2(123.5°E) could support FengYun dual-GEO. AMV study and the CMA/NSMC FY-2 dual-GEO. AMV prototype system will set up.

Fig 11 Diagram of Fengyun dual-GEO. AMV
5. REFERENCE:


