A New Atmospheric Motion Vector Intercomparison Study

David Santek¹, Javier García-Pereda², Chris Velden¹, Iliana Genkova³, Dave Stettner¹, Steve Wanzong¹, Sharon Nebuda¹, Régis Borde⁴, Manuel Carranza⁴

¹Cooperative Institute for Meteorological Satellite Studies
²NWCSAF/AEMET
³IMSG/NOAA/NCEP
⁴EUMETSAT

Twelfth International Winds Workshop
Copenhagen, Denmark
17 June 2014
Outline

- Project Overview
- Participants
- Data
- Description and Highlights of Four Experiments
- Summary of Findings
The goal of this study is to:

- Include the NWC SAF/HRW algorithm in the intercomparison studies
  - Quantify its performance, relative to the other AMV algorithms

- Update the results of the previous AMV intercomparison studies
  - Operational AMV algorithms may have changed since the last study

- Perform follow up studies as identified in the previous intercomparison work
  - Consider specific characteristics of the input data and AMV output
Participants

EUM: EUMETSAT
CMA: China Meteorological Administration
JMA: Japan Meteorological Agency
NOA: National Oceanic and Atmospheric Administration
KMA: Korea Meteorological Administration
NWC: Satellite Application Facility on Support to Nowcasting & Very Short Range Forecasting
BRZ: Brazilian Meteorological Center
Dataset: Input

- Triplet of infrared (10.8µ) Meteosat-9, full–disk images from 17 September 2012 at 1200, 1215, 1230 UTC

- 6.3µ, 7.2µ, 12.0µ and 13.4µ images for cloud height (Exp. 4)

- MPEF products “Scene Type and Quality” and “Cloud Analysis” (Exp. 4)

- ECMWF forecast grids: 12- and 18-hour forecast from 0000 UTC on 17 September 2012

Meteosat-9 10.8 µm from 17 September 2012 at 1215 UTC
Dataset: Output

- Text files containing these parameters: latitude, longitude, speed direction, pressure, QI without forecast, QI with forecast, horizontal and vertical pixel displacement
Experiment 1

• AMV producers extract IR10.8μ channel AMVs considering a triplet of images with a known displacement:
  o Test the tracking step in all AMV algorithms
  o Test geolocation and displacement calculation

• Fixed displacement of four elements and two lines were applied to a single image
  o Create an artificial triplet
Experiment 1
Displacement

- There were two positive results:
  - All AMV algorithms detected this shift correctly
  - Generally with no more than 0.1 pixel error
Experiment 1
Displacement Differences

- There were two positive results:
  - There were 10876 colocated vectors
  - Distance threshold of 35 km
  - The differences of horizontal and vertical displacements between EUM and each of the other centres were not statistically significant
Experiment 1
Speed Differences

0.1 displacement in subpixel tracking results in speed difference:

- 0.3 ms\(^{-1}\) at the satellite subpoint
- 1.3 ms\(^{-1}\) at 50°N 50°W
Experiment 1
Speed Differences

- BRZ and CMA appear to have an AMV speed dependence on distance from satellite subpoint
Experiment 2

- AMV producers extract IR10.8 µ channel AMVs with their standard AMV algorithm configuration:
  - Use only the MSG/SEVIRI IR10.8 µ images and the ECMWF model data for height assignment.
  - Test the target selection, tracking, and quality control steps
Experiment 2
Bulk Statistics

- The bulk distribution of AMV height is highly variable among the different centres
  - All are required to use only the IR $T_B$
  - Variability due to how representative $T_B$ is determined
Experiment 2
Colocation Differences

- 7050 colocated AMVs (QI no forecast > 50)
  - Mean speed differences 0.3 to 1.0 ms\(^{-1}\)
  - AMV pressures are all statistically different
    - Differences ranging from 30 to 80 hPa
    - Largest differences when compared to EUM: up to 130 hPa
  - All point to IR \(B_T\) height assignment not performing well
Experiment 2
Colocation Differences

Speed

Direction

Pressure
## Experiment 2

### Rawinsonde Comparison

**QI no forecast > 50**

<table>
<thead>
<tr>
<th>Site</th>
<th>N</th>
<th>P bias</th>
<th>P RMS</th>
<th>SpdBias</th>
<th>SpdRMS</th>
<th>DirBias</th>
<th>VecRMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRZ</td>
<td>63</td>
<td>0.67</td>
<td>18.81</td>
<td>0.14</td>
<td>5.27</td>
<td>-11.12</td>
<td>9.59</td>
</tr>
<tr>
<td>EUM</td>
<td>268</td>
<td>-0.53</td>
<td>26.57</td>
<td>3.09</td>
<td>7.24</td>
<td>0.05</td>
<td>9.43</td>
</tr>
<tr>
<td>JMA</td>
<td>177</td>
<td>-2.20</td>
<td>26.26</td>
<td>0.36</td>
<td>6.04</td>
<td>6.07</td>
<td>8.04</td>
</tr>
<tr>
<td>KMA</td>
<td>1346</td>
<td>1.19</td>
<td>24.98</td>
<td>-0.02</td>
<td>5.94</td>
<td>9.04</td>
<td>7.91</td>
</tr>
<tr>
<td>NOA</td>
<td>361</td>
<td>-1.59</td>
<td>27.14</td>
<td>3.08</td>
<td>6.30</td>
<td>12.84</td>
<td>8.94</td>
</tr>
<tr>
<td>NWC</td>
<td>2410</td>
<td>-1.86</td>
<td>26.03</td>
<td>-0.78</td>
<td>4.75</td>
<td>1.53</td>
<td>6.14</td>
</tr>
</tbody>
</table>

**QI with forecast > 50**

<table>
<thead>
<tr>
<th>Site</th>
<th>N</th>
<th>P bias</th>
<th>P RMS</th>
<th>SpdBias</th>
<th>SpdRMS</th>
<th>DirBias</th>
<th>VecRMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMA</td>
<td>241</td>
<td>3.60</td>
<td>26.33</td>
<td>0.17</td>
<td>7.51</td>
<td>5.05</td>
<td>8.99</td>
</tr>
<tr>
<td>EUM</td>
<td>283</td>
<td>-0.71</td>
<td>26.15</td>
<td>2.74</td>
<td>7.07</td>
<td>0.57</td>
<td>9.46</td>
</tr>
<tr>
<td>JMA</td>
<td>169</td>
<td>-2.50</td>
<td>26.81</td>
<td>0.14</td>
<td>5.09</td>
<td>3.52</td>
<td>7.04</td>
</tr>
<tr>
<td>KMA</td>
<td>1266</td>
<td>1.24</td>
<td>24.92</td>
<td>0.18</td>
<td>5.81</td>
<td>8.35</td>
<td>7.79</td>
</tr>
<tr>
<td>NOA</td>
<td>342</td>
<td>-1.23</td>
<td>27.27</td>
<td>3.17</td>
<td>6.18</td>
<td>14.21</td>
<td>8.87</td>
</tr>
<tr>
<td>NWC</td>
<td>2410</td>
<td>-1.89</td>
<td>25.97</td>
<td>-0.72</td>
<td>4.68</td>
<td>1.52</td>
<td>6.06</td>
</tr>
</tbody>
</table>

**Yellow:** Maximum difference  
**Cyan:** Minimum difference
### Experiment 2

**Background Comparison**

<table>
<thead>
<tr>
<th>Exp</th>
<th>QI</th>
<th>N</th>
<th>BFN</th>
<th>V_O</th>
<th>RMSE</th>
<th>VAF</th>
<th>RAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRZ</td>
<td>QINF:80-100</td>
<td>745</td>
<td>113</td>
<td>7.51</td>
<td>8.89</td>
<td>7.04</td>
<td>8.64</td>
</tr>
<tr>
<td>CMA</td>
<td>QINF:80-100</td>
<td>3964</td>
<td>755</td>
<td>7.07</td>
<td>8.22</td>
<td>6.44</td>
<td>7.81</td>
</tr>
<tr>
<td>EUM</td>
<td>QINF:80-100</td>
<td>5378</td>
<td>1003</td>
<td>6.88</td>
<td>9.73</td>
<td>6.47</td>
<td>9.54</td>
</tr>
<tr>
<td>JMA</td>
<td>QINF:80-100</td>
<td>3498</td>
<td>955</td>
<td>4.50</td>
<td>6.05</td>
<td>3.71</td>
<td>5.52</td>
</tr>
<tr>
<td>KMA</td>
<td>QINF:80-100</td>
<td>26427</td>
<td>5189</td>
<td>5.95</td>
<td>7.88</td>
<td>5.49</td>
<td>7.61</td>
</tr>
<tr>
<td>NOA</td>
<td>QINF:80-100</td>
<td>8180</td>
<td>1640</td>
<td>6.87</td>
<td>8.79</td>
<td>6.22</td>
<td>8.37</td>
</tr>
<tr>
<td>NWC</td>
<td>QINF:80-100</td>
<td>49331</td>
<td>11963</td>
<td>4.62</td>
<td>5.52</td>
<td>4.05</td>
<td>5.06</td>
</tr>
</tbody>
</table>

- **QI without forecast > 80**
- **N** = total number of AMVs
- **BFN** = Best Fit number of AMVs
- **V_O** = VD OMB mean
- **RAF** = RMSE after Best Fit
- **VAF** = Vector difference after Best Fit
- **RMSE** = root mean square error

**Yellow**: Maximum difference  \[ \text{Cyan} \]: Minimum difference
Experiment 2
Best Fit

Height assignment behaving differently for different centres

Best Fit pressure change by low, middle, high
Experiment 3

- AMV producers extract IR10.8 µ channel AMVs considering a prescribed AMV algorithm configuration
  - 24x24 target box; 80x80 search box
  - Use only the MSG/SEVIRI IR10.8 µ images and the ECMWF model data for the height assignment
  - Test tracking and quality control steps, considering similar targets
Experiment 3

Highlights

• Prescribed target and search box sizes
  ○ Number of winds QI > 50 range from 2300 to 9600
    ○ Exp. 2: 4900 to 75000

• Very few collocated vectors
  ○ Only 370 matches
    ○ Good agreement of speed and direction among centres

• Better homogeneity of data because of prescribed configuration
Experiment 3
Speed and Direction Differences

Speed (top) and direction (lower)
Experiment 4

- AMV producers extract IR10.8 μ channel AMVs considering a **prescribed** AMV algorithm configuration
  - 24x24 target box; 80x80 search box
  - Use the height assignment method of their choosing
  - Test the height assignment and quality control steps considering similar targets
Experiment 3 vs. 4

Large shift in height histograms

Height change between Experiments 3 and 4
Experiment 3 vs. 4

Height change between Experiments 3 and 4

Exp. 3 JMA

Exp. 4 CMA
Experiment 3 vs. 4

Height change between Experiments 3 and 4
Experiment 4
Rawinsonde Comparison

QI with forecast > 50

Substantial improvement in the vector RMS with rawinsonde comparisons between Experiments 3 and 4 for
- EUM: from 9.46 to 6.26 ms\(^{-1}\)
- NOA: from 9.30 to 7.36 ms\(^{-1}\)
## Experiment 4

### Background Comparison

<table>
<thead>
<tr>
<th>Exp</th>
<th>QI</th>
<th>N</th>
<th>BFN</th>
<th>V_O</th>
<th>RMSE</th>
<th>VAF</th>
<th>RAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRZ</td>
<td>QINF:80-100</td>
<td>1590</td>
<td>220</td>
<td>8.01</td>
<td>9.67</td>
<td>7.54</td>
<td>9.43</td>
</tr>
<tr>
<td>CMA</td>
<td>QIWF:80-100</td>
<td>4743</td>
<td>1090</td>
<td>6.38</td>
<td>7.44</td>
<td>5.77</td>
<td>7.02</td>
</tr>
<tr>
<td>EUM</td>
<td>QIWF:80-100</td>
<td>6583</td>
<td>2301</td>
<td>3.91</td>
<td>5.36</td>
<td>3.29</td>
<td>4.84</td>
</tr>
<tr>
<td>JMA</td>
<td>QINF:80-100</td>
<td>3514</td>
<td>1056</td>
<td>4.91</td>
<td>6.69</td>
<td>3.94</td>
<td>5.88</td>
</tr>
<tr>
<td>KMA</td>
<td>QINF:80-100</td>
<td>4574</td>
<td>1221</td>
<td>5.16</td>
<td>6.83</td>
<td>4.66</td>
<td>6.52</td>
</tr>
<tr>
<td>NOA</td>
<td>QINF:80-100</td>
<td>2274</td>
<td>807</td>
<td>5.90</td>
<td>7.54</td>
<td>4.84</td>
<td>6.83</td>
</tr>
<tr>
<td>NWC (Oper.conf, EUM Clouds)</td>
<td>QINF:80-100</td>
<td>53010</td>
<td>18115</td>
<td>3.23</td>
<td>4.15</td>
<td>2.71</td>
<td>3.65</td>
</tr>
<tr>
<td>NWC (Oper.conf, NWC Clouds)</td>
<td>QINF:80-100</td>
<td>52464</td>
<td>18732</td>
<td>3.77</td>
<td>4.65</td>
<td>3.05</td>
<td>4.04</td>
</tr>
<tr>
<td>NWC (Pres.conf, EUM Clouds)</td>
<td>QINF:80-100</td>
<td>1419</td>
<td>605</td>
<td>3.05</td>
<td>4.01</td>
<td>2.45</td>
<td>3.40</td>
</tr>
</tbody>
</table>

QI without forecast > 80

N = total number of AMVs

BFN = Best Fit number of AMVs

V_O = VD OMB mean

RAF = RMSE after Best Fit

VAF = Vector difference after Best Fit

RMSE = root mean square error

**Yellow:** Maximum difference  **Cyan:** Minimum difference
Experiment 4
Additional Graphs
Before and after Best Fit speed and vector difference
Experiment 4
Additional graphs

Best Fit distribution
latitude, longitude, height, pressure change
Conclusions

EUMETSAT

- The strengths of the algorithm were especially noted in Experiment 4. The statistical comparison of the EUM AMVs to rawinsondes and the background forecast wind field, was second only to NWCSAF.

- However, the use of only the IR $B_T$ for cloud height (Experiment 3) resulted in AMVs being placed several hundred hPa different than when other techniques could be used (Experiment 4).
Conclusions

CMA

- AMV comparison to rawinsondes and the background wind field exhibited larger errors than other centres. May be due to very extensive use of IR-only $B_T$ in determining AMV heights.

- However, the Best Fit analysis indicates that there are good AMVs in this dataset as Best Fit height adjustment and corresponding improvement in statistics (compared to the background) are very similar to other centres.
Conclusions

JMA

• The results from Experiment 4 show that the JMA algorithm is in the middle (statistically) when measuring performance based on comparisons to rawinsondes and the background wind field.
Conclusions

NOAA

- The strength of the NOAA algorithm is its cloud height determination as evidenced in Experiment 4: A substantial number of heights were adjusted (as compared to IR-only $B_T$) resulting in an improvement in a statistical comparison to rawinsondes and the background forecast wind field.

- Unfortunately, they were not able to use a high vertical resolution background grid, to better detect temperature inversions and the height of low-level clouds.
Conclusions

KMA

- The results from Experiment 4 show that the KMA algorithm is in the middle (statistically) when measuring performance based on comparisons to rawinsondes and the background wind field.
Conclusions

Brazil

- The performance of the BRZ AMV algorithm could not be evaluated because the results of Experiment 1 indicates an error in determining wind speed up to 10 ms\(^{-1}\) depending on the distance from the satellite subpoint.

- However, the Best Fit analysis indicates that there are good AMVs in this dataset as the Best Fit height adjustment and corresponding improvement in statistics (compared to the background) are very similar to other centres.
Conclusions
NWC/SAF

• Among all the centres in this study, the NWCSAF/HRW algorithm had the best statistics as compared to rawinsondes and the background forecast wind field. This was the case for both Experiment 3 (IR $B_T$ only cloud height) and Experiment 4 (any cloud height technique).

• Moreover, NWC AMVs with IR-only cloud height performed better than several other centres using other cloud height techniques.
Thank You!
EUM and CMA
EUM and JMA
EUM and BRZ
EUM and KMA
EUM and NOA
EUM and NWC