AVHRR Polar Winds Derivation at EUMETSAT: Current Status and Future Developments

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Background

- METOP-A polar orbiting satellite launched October 2006

- Operated by EUMETSAT

- Joint European-US satellite system agreement foresees that both NOAA and EUMETSAT derive and provide polar wind data to users

- NOAA generate polar winds data from METOP AVHRR IR channel
Overview of EUMETSAT Implementation

• Prototype Development based on CIMSS Polar Winds Code

• Operational Development

• Validation of operational version using prototype, ECMWF re-analysis, radiosonde data

• Pre-operational availability of products

• Assimilation experiments at ECMWF

• Routine Operations
Prototype

- Off-line post-processing tool - adapted CIMSS Polar Winds Code
- Mapping onto a polar stereographic grid
  - winds output twice per orbit (North, South Pole regions)
- Generates winds using triplets, ie sequences of 3 overlapping orbits
- Uses forecast data to provide a first guess of tracked target position
- IR window height assignment and RFF to adjust heights
Prototype Example

AVHRR polar cap wind fields

Arctic

Antarctic
Prototype Production Data Sets

- January 2009 AVHRR winds data set

- Co-locations with METOP-A IASI instrument derived cloud top information (CO2 slicing method – potentially better for thin clouds)

- Data sets
  - winds co-located with IASI heights (prototype heights)
  - winds co-located with IASI heights (IASI heights)
Prototype Data Sets ECMWF Observation Departures

North Pole
All AMVs, QI ≥ 80
Prototype Heights – red
IASI Heights - black
Prototype Data Sets ECMWF Observation Departures

South Pole
All AMVs, QI≥80
Prototype Heights – red
IASI Heights - black
Prototype Data Sets Height Coverage

IASI version > 27 January 2009 – heights adjusted downwards

IASI Height Assignment Implementation further upgrades in pipeline
Z norm diff of the RMS of FC Error as a function of forecast range – NH positive diff -> positive impact
Z norm diff of the RMS of FC Error as a function of forecast range – SH positive diff -> positive impact
Z norm diff of the RMS of FC Error as a function of forecast range – TR positive diff -> positive impact
Prototype Data Sets ECMWF Impact Conclusions

- EUM Prototype (CIMSS height assignment) Polar Winds data set for January 2009 has a neutral impact on forecast.

- Local 'positive' and 'negative' forecast impact regions are alternating and they don't show any trends.

- IASI height assignment produces worse departure statistics - improvements expected.

- ECMWF ideally require longer than one month worth of data.
EUMETSAT Operational Version Winds Derivation

- All Level 2 wind products processed in NRT using 3 minute (PDU) image data at a time, nominal processing time 3 minutes

- Only use 2 orbits to produce the winds for each PDU

- For each target PDU – map the 3 search PDUs in the previous orbit which overlap onto the target PDU co-ordinate system

- Tracking between pairs of images (current and previous orbit)

- Disseminated between 90 and 110 minutes after sensing time
Tracking Issues

- Use/non-use of forecast first guess information

- Tracking methods
  - cross-correlation, euclidean distance, centre of mass

- Pixel size - normal, super 3x3, super 9x9

- Target size - 28 x 28, 152 x 152

- Pyramid approach: large target and search area -> 1st estimate
  - small target and search area centred on 1st estimate
Tracking Methodology – no forecast, large search area

Target Size 28x28

Target Size 152 x 152

Option without first guess – need large target size
Tracking Methodology – forecast first guess, small search area

Option with first guess – can use small target size
QI Issues

• Spatial and Forecast Consistency

• **Tracking Consistency**
  - track target from current to previous orbit
  - track target from previous orbit back again to current orbit
  - use vector, speed, direction differences as an indication of tracking consistency

• **Temporal Height Consistency**
  - separate height assignments for target in both orbits
  - use height differences as an indication of consistency
Preliminary Validation Overview

- Prototype
- Pre-Operational – forecast guided (small target size 28 x 28)
- Pre-Operational – no forecast guide (large target size 152 x 152)

- Validation against ECMWF re-analysis

QI filtering
- prototype QI > 60
- pre-operational (forecast) QI > 50
- pre-operational (non-forecast guided) QI > 50
- removes about 50 % of winds
### AVHRR Winds vs Re-Analysis Sample One Day

#### Arctic (Red) vs Antarctic (Blue)

<table>
<thead>
<tr>
<th>Metric</th>
<th>Prototype</th>
<th>Forecast First GUESS (GS2)</th>
<th>No Forecast (GS3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed Bias (m/s)</td>
<td>-1.21</td>
<td>0.87</td>
<td>-1.45</td>
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<tr>
<td>Speed RMS (m/s)</td>
<td>2.67</td>
<td>4.50</td>
<td>8.21</td>
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<tr>
<td>Direction Bias (deg)</td>
<td>1.00</td>
<td>0.45</td>
<td>5.05</td>
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<tr>
<td>Direction RMS (deg)</td>
<td>8.60</td>
<td>15.65</td>
<td>59.40</td>
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<tr>
<td>Mean Speed AMV</td>
<td>19.47</td>
<td>21.52</td>
<td>16.90</td>
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<tr>
<td>Mean Speed Analysis</td>
<td>20.69</td>
<td>20.65</td>
<td>18.35</td>
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<tr>
<td>Sample size</td>
<td>3988</td>
<td>970</td>
<td>1035</td>
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</table>

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<thead>
<tr>
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<th>Prototype</th>
<th>Forecast First GUESS (GS2)</th>
<th>No Forecast (GS3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed Bias (m/s)</td>
<td>-0.10</td>
<td>1.72</td>
<td>-0.02</td>
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<tr>
<td>Speed RMS (m/s)</td>
<td>2.01</td>
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<td>5.30</td>
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<tr>
<td>Direction Bias (deg)</td>
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<td>2.25</td>
<td>11.39</td>
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<tr>
<td>Direction RMS (deg)</td>
<td>13.33</td>
<td>38.45</td>
<td>66.91</td>
</tr>
<tr>
<td>Mean Speed AMV</td>
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<td>12.83</td>
<td>7.65</td>
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<tr>
<td>Mean Speed Analysis</td>
<td>14.79</td>
<td>11.11</td>
<td>7.66</td>
</tr>
<tr>
<td>Sample size</td>
<td>1503</td>
<td>393</td>
<td>947</td>
</tr>
</tbody>
</table>

- Prototype departure statistics better
- Forecast guided winds better departure statistics
- Height distribution predominantly medium level (400 – 700 hPa)
Validation Activities Leading Up To Operations

- More statistics over longer time periods, inc. radiosonde
- Isolate and filter out areas in which quality is lower
- Fine tuning of processing parameters eg QI weights
- Comparison of forecast and non-forecast guided winds

- Pre-operational availability (test products available for ECMWF test dissemination) est > May 2010
Error Sources

- **Tracking**
  - feature changes significantly in 100 minutes
  - feature tracked representative of flow?
  - parallax (more at extreme viewing geometry)
  - correlation surface peak analysis
  - if using forecast as first guess, impacted by errors in height assign

- **Height Assignment**
  - IR Window for thin clouds
  - IASI height assignment
  - temperature inversions
Degradation in Tracking Quality

• Illustration of deterioration in tracking quality as time interval between successive images increases and the feature correspondingly changes

• Examples using Meteosat Second Generation Images
  - tracking intervals 15, 30, 45, 60, 75, 90, 105 minutes
  - search area increasingly expanded with time about target centre to contain the feature movement
  - IR channel 24x24 target sizes
  - HRVIS 32x32, 48x48, 96x96 target sizes
MSG IR – 24x24 pixel target 15 minute tracking interval
MSG IR – 24x24 pixel target 30 minute tracking interval
MSG IR – 24x24 pixel target 45 minute tracking interval
MSG IR – 24x24 pixel target 60 minute tracking interval
MSG IR – 24x24 pixel target 75 minute tracking interval
MSG IR – 24x24 pixel target 90 minute tracking interval
MSG IR – 24x24 pixel target 105 minute tracking interval
MSG HRVIS – 32x32 pixel target 15 minute tracking interval: QI > 80
MSG HRVIS – 32x32 pixel target 30 minute tracking interval: QI > 80
MSG HRVIS – 32x32 pixel target 45 minute tracking interval: QI > 80
MSG HRVIS – 32x32 pixel target 60 minute tracking interval: QI > 80
MSG HRVIS – 32x32 pixel target 75 minute tracking interval: QI > 80
MSG HRVIS – 32x32 pixel target 90 minute tracking interval: QI > 80
MSG HRVIS– 32x32 pixel target 105 minute tracking interval: QI > 80
60 MINUTE INTERVAL : QI > 80

IMPACT OF TARGET SIZE

32 x 32  (Top Left)
48 x 48  (Top Right)
96 x 96  (Bottom)
Degradation in Tracking Quality Conclusions

- Tracking severely degraded for time intervals above 60 minutes
  - even if the feature is contained in the expanded search area
  - even if forecast estimate good

- Degradation can be reduced by increasing the target size

- METOP-B to be launched April 2012

- Recommendation to investigate combining METOP-A and METOP-B images (separation of 50 minutes)
Future Plans

- Monitor differences between forecast/non-forecast guided winds
- Incorporation of IASI height assignment information
- Height assignment improvements eg low-level clouds
- Use of 2 satellites – expected to significantly improve tracking quality
  - Metop B scheduled for launch Apr 2012
- Parallax consideration
- Consideration of triplets
  - feature tracked for 200 minutes
  - delay winds availability by 100 mins : availability 190 to 210 mins
- Additional receiver station in Antarctic – improve timeliness
- Improvements to quality filtering