Introducing Atmospheric Motion Vectors Derived from the GOES-16 Advanced Baseline Imager (ABI)

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Outline

• GOES-16 Advanced Baseline Imager (ABI)

• Review of the GOES-16 ABI Winds Product Specifications and Algorithm

• GOES-16 ABI Wind Product Examples

• GOES-16 Winds Validation Results

• Summary and Future Plans
Outline

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GOES-16 ABI Enhanced Capabilities

- **Higher Spectral Resolution**
  - Can see and retrieve new phenomena

- **Higher Spatial Resolution**
  - Higher fidelity imagery and L2 products; information at smaller scales now observed

- **Higher Temporal Resolution**
  - Physical and dynamical processes are now captured; new information to exploit and be used by user community

- **Improved Radiometrics**
  - Translate to more accurate products

- **Improved Navigation and Registration**
  - More accurate products and improved utilization of them

All of these things contribute to one being able to observe and retrieve phenomenon not previously observed before.
Advanced Baseline Imager (ABI)

Current Operational ABI

Scan Modes:

Mode 3:
- Full disk images every 15 minutes
- CONUS images every 5 minutes
- Mesoscale images (2) every 1 minute

Mode 4:
- Full disk images every 5 minutes

Future Potential Operational ABI

Scan Mode:

Mode 6:
- Full disk images every 10 minutes
- CONUS images every 5 minutes
- Mesoscale images (2) every 1 minute

AMV Product Refresh Rate:

- Full Disk: Hourly
- CONUS: 15 minutes
- Meso: 5 minutes
# ABI Visible/Near-IR Bands

<table>
<thead>
<tr>
<th>Future GOES imager (ABI) band</th>
<th>Wavelength range (µm)</th>
<th>Central wavelength (µm)</th>
<th>Nominal subsatellite IGFOV (km)</th>
<th>Sample use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.45–0.49</td>
<td>0.47</td>
<td>1</td>
<td>Daytime aerosol over land, coastal water mapping</td>
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<tr>
<td>2</td>
<td>0.60–0.68</td>
<td>0.64</td>
<td>0.5</td>
<td>Daytime clouds fog, insolation, winds</td>
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<tr>
<td>3</td>
<td>0.847–0.882</td>
<td>0.864</td>
<td>1</td>
<td>Daytime vegetation/burn scar and aerosol over water, winds</td>
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<tr>
<td>4</td>
<td>1.366–1.380</td>
<td>1.373</td>
<td>2</td>
<td>Daytime cirrus cloud</td>
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<tr>
<td>5</td>
<td>1.59–1.63</td>
<td>1.61</td>
<td>1</td>
<td>Daytime cloud-top phase and particle size, snow</td>
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<tr>
<td>6</td>
<td>2.225–2.275</td>
<td>2.24</td>
<td>2</td>
<td>Daytime land/cloud properties, particle size, vegetation, snow</td>
</tr>
<tr>
<td>Future GOES imager (ABI) band</td>
<td>Wavelength range (μm)</td>
<td>Central wavelength (μm)</td>
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<tr>
<td>7</td>
<td>3.80-3.99</td>
<td>3.90</td>
<td>2</td>
<td>Surface and cloud, fog at night, fire, winds</td>
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<tr>
<td>8</td>
<td>5.79-6.59</td>
<td>6.19</td>
<td>2</td>
<td>High-level atmospheric water vapor, winds, rainfall</td>
</tr>
<tr>
<td>9</td>
<td>6.72-7.14</td>
<td>6.93</td>
<td>2</td>
<td>Midlevel atmospheric water vapor, winds, rainfall</td>
</tr>
<tr>
<td>10</td>
<td>7.24-7.43</td>
<td>7.34</td>
<td>2</td>
<td>Lower-level water vapor, winds, and SO₂</td>
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<tr>
<td>11</td>
<td>8.23-8.66</td>
<td>8.44</td>
<td>2</td>
<td>Total water for stability, cloud phase, dust, SO₂ rainfall</td>
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<tr>
<td>12</td>
<td>9.42–9.8</td>
<td>9.61</td>
<td>2</td>
<td>Total ozone, turbulence, and winds</td>
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<tr>
<td>13</td>
<td>10.18-10.48</td>
<td>10.33</td>
<td>2</td>
<td>Surface and cloud</td>
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<tr>
<td>14</td>
<td>10.8–11.6</td>
<td>11.2</td>
<td>2</td>
<td>Imagery, SST, clouds, rainfall</td>
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<tr>
<td>15</td>
<td>11.8–12.8</td>
<td>12.3</td>
<td>2</td>
<td>Total water, ash, and SST</td>
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<tr>
<td>16</td>
<td>13.0–13.6</td>
<td>13.3</td>
<td>2</td>
<td>Air temperature, cloud heights and amounts</td>
</tr>
</tbody>
</table>
GOES-16 ABI Frame-to-Frame Registration

GOES-16 ABI Frame to Frame Registration
29 Nov 2017 - 1800 UTC vs 29 Nov 2017 - 1815 UTC

X-FFR by channel

X-FFR STD by channel

Y-FFR by channel

Y-FFR STD by channel

GOES-16 ABI Frame-to-frame registration is excellent!!!

Critical for accurate feature tracking.

Figure courtesy Vladimir Kondratovich (GOES-R CWG)
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# GOES-16 Winds Product Specifications

<table>
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<th>Wind Product Capabilities</th>
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<tr>
<td><strong>Satellite Source</strong></td>
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<td><strong>Wind Product Types</strong></td>
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<td><strong>Coverage</strong></td>
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<td><strong>Refresh</strong></td>
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<td><strong>Horizontal Resolution</strong></td>
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<td><strong>Accuracy</strong></td>
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<td><strong>Precision</strong></td>
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<tr>
<td><strong>Other Attributes</strong></td>
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</tbody>
</table>
GOES-R Winds Algorithm
Precedence Chain

1. Clear Sky Mask
2. Cloud Type/Phase
3. Cloud-top Temperature & Pressure
4. Winds
GOES-16 Winds Algorithm Overview

Nested Tracking Approach...

- Correlation based approach used to compute local motions (nested) within a larger target scene.

- A clustering algorithm is applied to line and element displacements to extract motion solution(s).

- Cloud heights at pixels belonging to the largest cluster are used to assign a representative height (Median) to the derived motion wind.

- Potential for determination of motion at different levels and/or different scales

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GOES-R Winds Product
Precedence Chain

Clear Sky Mask

Cloud Type/Phase

Cloud-top Temperature & Pressure

Winds
• **Cloud Height Algorithm Highlights**
  - Algorithm uses the 11, 12 and 13.3mm channels to retrieve cloud-top temperature. Cloud emissivity and a cloud microphysics are retrieved as well.
  - Algorithm (1-D VAR) uses an optimal estimation approach (Rogers, 1976) that provides error estimates ($T_c$).
  - NWP forecast temperature profiles used to compute cloud-top pressure and height.
  - For pixels typed as containing multi-layer clouds, a multi-layer solution is performed.
  - Special processing occurs in the presence of low level temperature inversions.

• **References**

*Andy Heidinger (NESDIS/STAR) – AWG Cloud Team Lead*
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GOES-16 Band 2 (0.64um) Visible Winds (Mode 3)
November 23 (00 UTC) – November 24 (23 UTC), 2017

These GOES-16 data are preliminary, non-operational data and are undergoing testing. Users bear all responsibility for inspecting the data prior to use and for the manner in which the data are utilized.
GOES-16 Band 7 (3.9um) SWIR Winds (Mode 3)
November 23 (00 UTC) – November 24 (23 UTC), 2017

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GOES-16 Winds

- GOES-16 Winds derived every 5 minutes from mesoscale sector imagery and plotted over top of the ABI Band 2 (0.64um) visible imagery.

- **Baseline** algorithms and associated configurations used

- **ABI bands used** to generate the winds shown in this loop:
  - **Band 2 (0.64um; 0.5km)**: Winds generated from cloud tracers at low levels of the atmosphere (below 700hPa) from this band
  - **Band 8 (6.2um; 2km)**: Winds generated from cloud tracers at upper levels (at and above 350 hPa) of the atmosphere from this band
  - **Band 14 (11.2um; 2km)**: Winds generated from cloud tracers at all levels (100-950 hPa) of the atmosphere from this band

**Note:** For clarity, not all AMVs are plotted

GOES-R AWG Winds Application Team
GOES-16 AMV Counts by Type Over a Typical FD

26-Jan-2018 Full Disk

0600 UTC Band 7
1800 UTC Bands 2, 8 (WVCT), 14
1830 UTC Bands 8, 9, 10 (all CSWV)
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GOES-16 wind product achieved a **beta level** of maturity on June 8, 2017

- Product has been minimally validated and may still contain significant errors.
- Product is not ready for operational use.

Numerous updates/fixes made to the wind product processing software between June and October 2017 to improve the stability and quality of the GOES-16 wind product

GOES-16 wind product achieved a **provisional level** of maturity on February 9, 2018

- Product performance has been demonstrated through analysis of a small number of independent measurements obtained from select locations, periods, and associated ground truth or field campaign efforts.
- Product analysis is sufficient to communicate product performance to users relative to expectations.
- Issues with products may still exist, but are documented and being worked
- Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.
GOES-16 ABI Winds vs. Rawinsonde Winds

Period: November 1-30, 2017
Full Disk

Results as of Feb 9, 2018

- Speed bias profile characteristics (band 14 and Band 8 AMVs) indicative of sub-optimal height assignments (coordinating closely with GOES-R cloud team)
- Sub-optimal internal AMV Quality Control (ie., gross error checking)
We recently tested an updated AMV gross error checking scheme (checks against GFS forecast wind).

New band dependent AMV/GFS wind vector difference thresholds:
- Band 2: 6 m/s
- Band 7: 7 m/s
- Band 8 (cloud): 10 m/s
- Band 14: 10 m/s
- Bands 8-10 (clear sky): 12 m/s

Estimated implementation dates into operations: June 2018

Implemented this in our offline, experimental, near real-time GOES-16 AMV data stream starting at ~00Z Friday (4/6).

New gross error checking has the intended effect:
- ~10-15% of the AMVs fail gross error checks
- Speed biases at mid levels improve
- Slow speed bias above 300mb still indicative of height assignment issues
Updated GOES-16 Cloud Height Algorithm

- We recently tested the impact of GOES-16 cloud-top height products from an updated cloud heights algorithm on GOES-16 AMV performance

- Estimated implementation dates into operations
  - Cloud Height Algorithm Updates: Oct 2018

- Implemented this in our offline, experimental, near real-time GOES-16 AMV data stream starting at ~00Z last Friday (4/6).
  (Available via anonymous ftp)

**Updated cloud height algorithm**

- Reduction in the slow wind speed bias at upper levels
- Slow wind speed bias in the 400-600 mb layer
Note the change in the distribution of AMV height assignments associated with updated cloud height algorithm, especially at upper levels.
Histograms GOES-16 AMV/Rawinsonde Departures

November 1-30, 2017

Speed Departures (AMV-Raob)  
Direction Departures (AMV-Raob)

CTPs from Baseline Cloud Height Algorithm and Baseline AMV gross error checks are used
CTPs from Updated Cloud Height Algorithm and Updated AMV gross error checks are used

Much improved speed departure histogram (shape and position) with updated CTPs and AMV gross error checking
Satellite winds within 150 km and 60 minutes of Belize radiosonde
Target scene is composed primarily of a single layer cloud. Some pixels with low cloud, but these pixels are not part of the largest tracking cluster.

Retrieved cloud top pressures are around 200 mb which are **too low (cloud heights too high) and not supported** by the collocated Belize radiosonde observations.
Latest version of cloud height algorithm produces a much improved cloud top pressures (near 375mb) which are *now consistent and supported by the Belize radiosonde observation*.

- Working on plans to implement latest version
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Summary and Future Plans

• Overall quality of the GOES-16 AMVs is good

• We’ve identified issues impacting the quality of the GOES-16 AMVs and are working to resolve them
  – AMV height assignment issues traced to sub-optimal cloud-top pressure retrieval product, especially for cirrus at upper levels of the atmosphere
  – Internal AMV Quality Control
  – NWP user feedback we’ve received about the GOES-16 AMVs is consistent with our validation findings
  – We’ve measured the impact of the fixes to these issues on the quality of the GOES-16 AMVs the impact is significant and positive

• We will be involved with Intensive calibration/validation of GOES-17 AMV products through August 2018
Questions

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