GOES-R AWG Winds Team: Derived Motion Winds

June 8, 2010

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The AWG Wind Team Members

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- **Winds Application Team**
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Special thanks to the Winds Development Team

Outline

- Executive Summary
- Requirements Specification Evolution
- Algorithm Description
- ADEB and IV&V Response Summary
- Validation Strategy
- Validation Results
- Summary

Executive Summary

- The Derived Motion Wind (DMW) algorithm generates atmospheric winds by tracking features (clouds, elevated moisture gradients) in satellite imagery
- The generation of GOES-R ABI wind products will ensure continuity of the wind product suite that is currently being generated operationally with today's GOES imager and sounder instruments.
- Version 4 DMW algorithm was delivered to the AIT in March 2010. Version 4 algorithm includes nested tracking (and associated height assignment) and Expected Error (EE) filtering
- Version 5 DMW and ATBD (100%) are on track for a July and June delivery
- Validation tools have been developed and run to validate the derived motion winds against radiosonde winds. Tools to validate against GFS analysis and CALIPSO data are in progress.
- Validation of winds generated from proxy SEVIRI data shows that the algorithm performance is meeting the Functional & Performance Specifications (F&PS) for accuracy and precision at the 100% level.

Requirements

Coverage	Horizontal Resolution	Measurement Range	Accuracy	Precision	Refresh Rate	Latency
Full Disk	38 km	**Speed:** 5.83-300 kts (3-155 m/s) **Direction:** 0 to 360 degrees	7.5 m/s	4.5 m/s	60 min (based on a single set of 3 sequential images 5 or more minutes apart)	806 s
CONUS	38 km	**Speed:** 5.83-300 kts (3-155 m/s) **Direction:** 0 to 360 degrees	7.5 m/s	4.5 m/s	15 min	806 s
Mesoscale	38 km	**Speed:** 5.83-300 kts (3-155 m/s) **Direction:** 0 to 360 degrees	7.5 m/s	4.5 m/s	5 min	806 s

Most recently approved changes

Qualifiers

- Day and night
- Sensor zenith angle < 70 degrees

Most recently approved changes

Algorithm Description

GOES-R Derived Motion Winds Algorithm Summary

Uses a sequence of images to arrive at an estimate of atmospheric motion for a set of targeted tracers/scenes viewed in selected spectral bands

» The choice of spectral band will determine the intended target (cloud or clear-sky moisture gradient) and location (low, mid, upper troposphere) in the atmosphere.

- **Select target tracers/scenes:**
  - » Contain sufficient contrast
  - » Do not contain multi-layered clouds
- **Estimate atmospheric motion**
  - » Targeted tracers/scenes are tracked forward and backward in time using a Sum-of-Squared Differences (SSD) pattern matching algorithm
  - » When LWIR (10.8um) and WV (6.2um) bands are used to track cloud tracers, a nested tracking algorithm approach is used. It uses the SSD algorithm, together with a clustering algorithm, to find the dominant motion in each target scene
  - » The predecessor pixel level cloud height products are used to compute a representative height for each derived motion wind
  - » Mean vector displacement computed over the time interval of the image triplet

Algorithm Summary *(cont'd)*

- **Application of Quality control**
  - » Flag suspect targets and vectors
  - » Compute and append quality indicators (EE and QI) to each vector

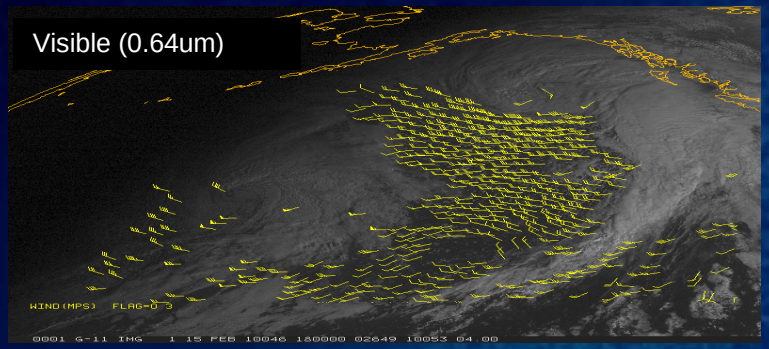
- **Products**
  - » Wind speed
  - » Wind direction
  - » Height (mb) assigned to each wind vector

Motivation for Algorithm Channel Selection

The choice of spectral band will determine the intended target (*cloud or clear-sky moisture gradient*) and location (*low, mid, upper troposphere*) in the atmosphere.

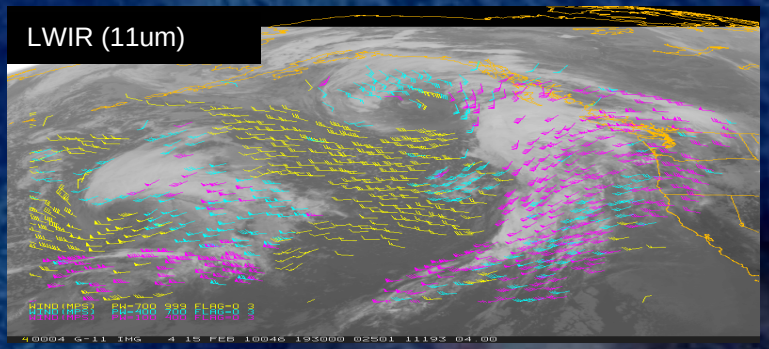
Visible Cloud-drift Winds

- Daytime, Lower troposphere



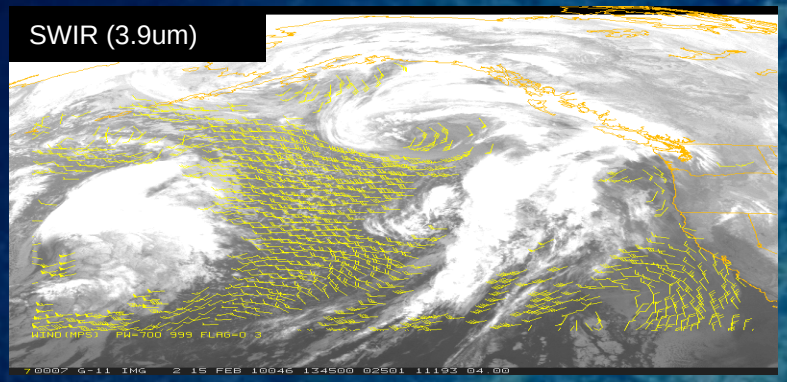
Long-wave IR Cloud-drift Winds

- Day and night; Lower, mid, and upper troposphere



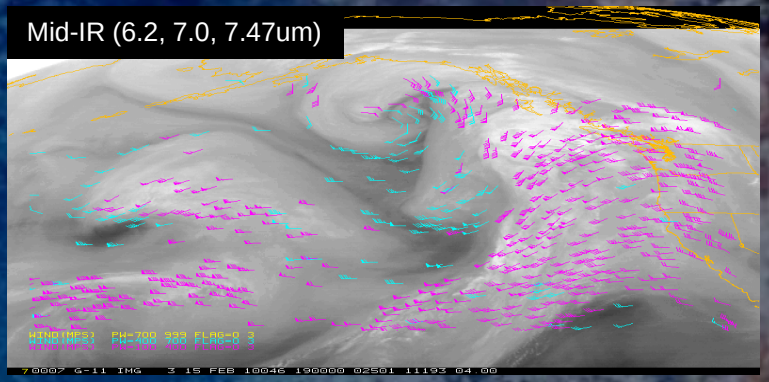
Short-wave IR Cloud-drift Winds

- Night-time, Lower troposphere



Water Vapor Winds

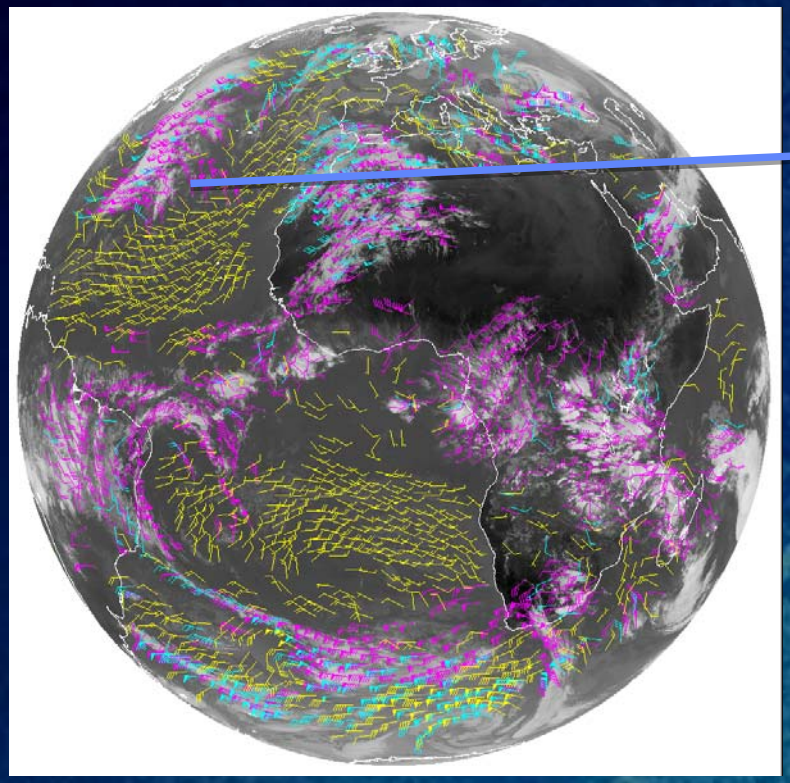
- Cloud-top and Clear-sky; Mid and Upper troposphere)

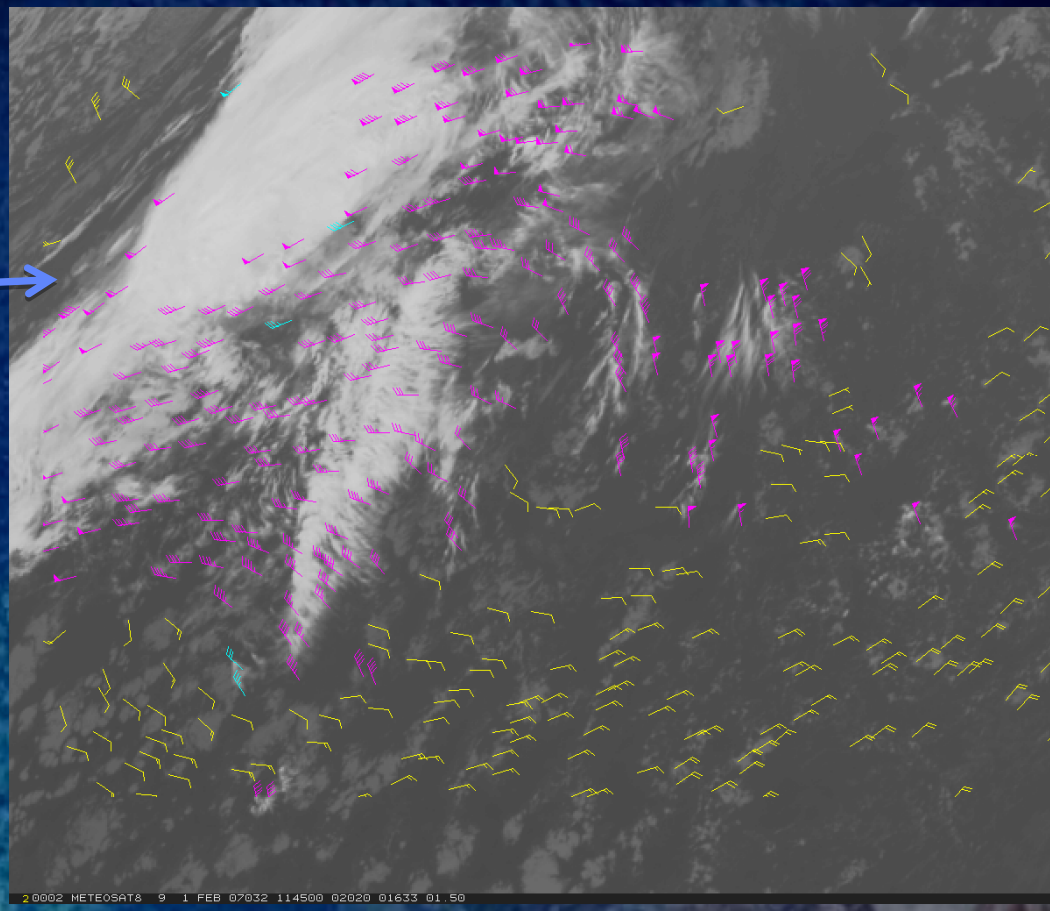


Example Output

Long-wave IR Cloud-drift Winds

Cloud-drift Winds derived from a Full Disk Meteosat-8 SEVERI 10.8 μm image triplet centered at 1200 UTC 01 February 2007





High-Level 100-400 mb

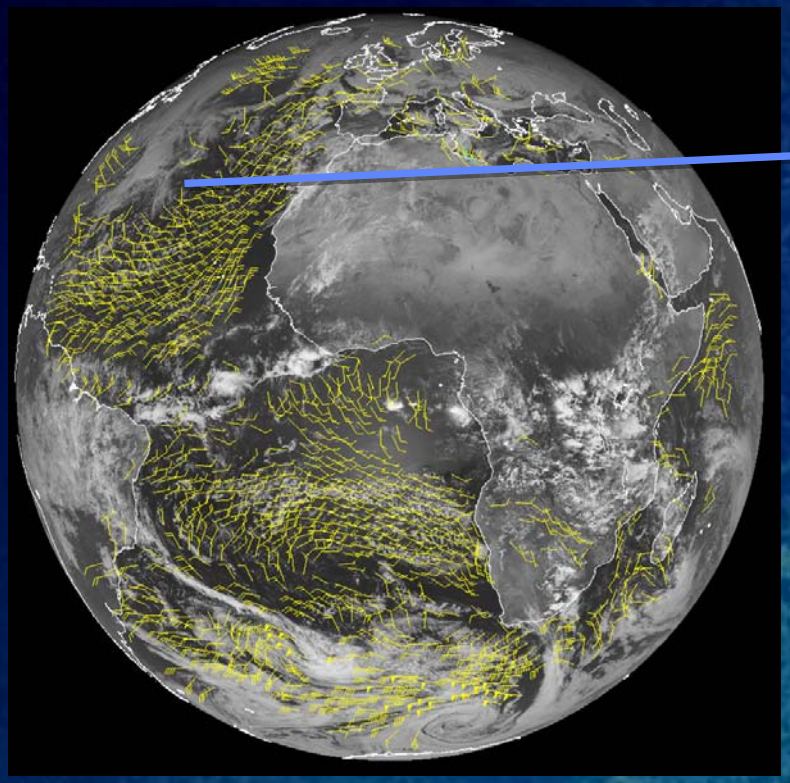
Mid-Level 400-700 mb

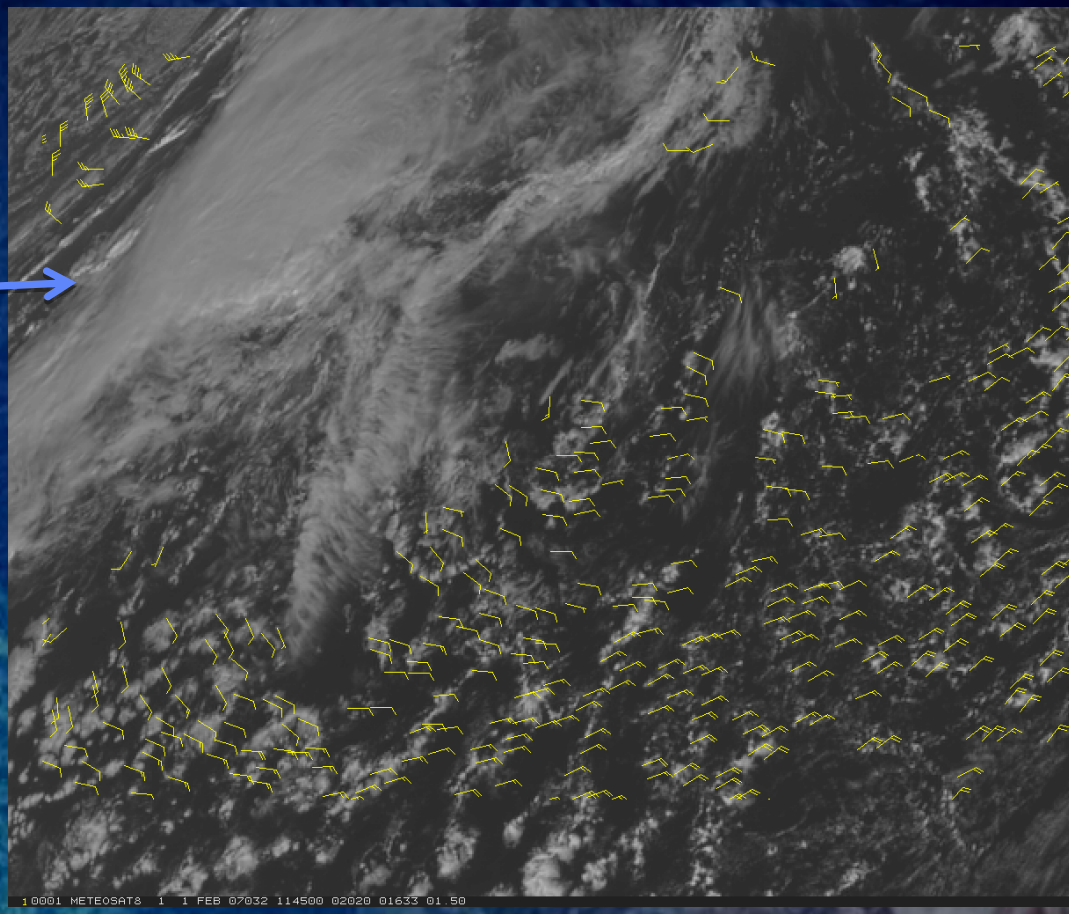
Low-Level >700 mb

Example Output

Visible Cloud-drift Winds

Cloud-drift Winds derived from a Full Disk Meteosat-8 SEVERI 0.60 um image triplet centered at 1200 UTC 01 February 2007



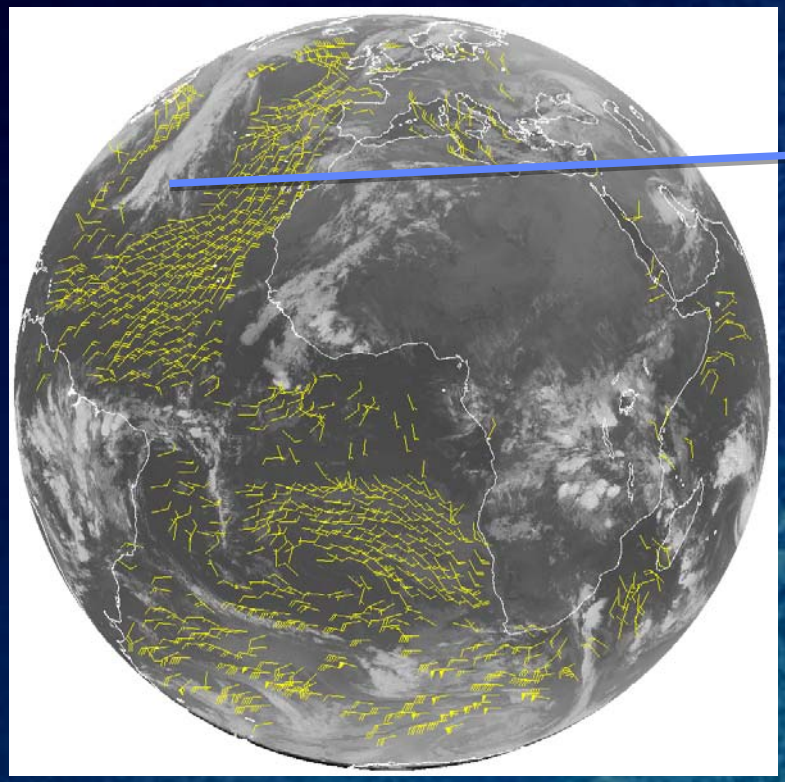


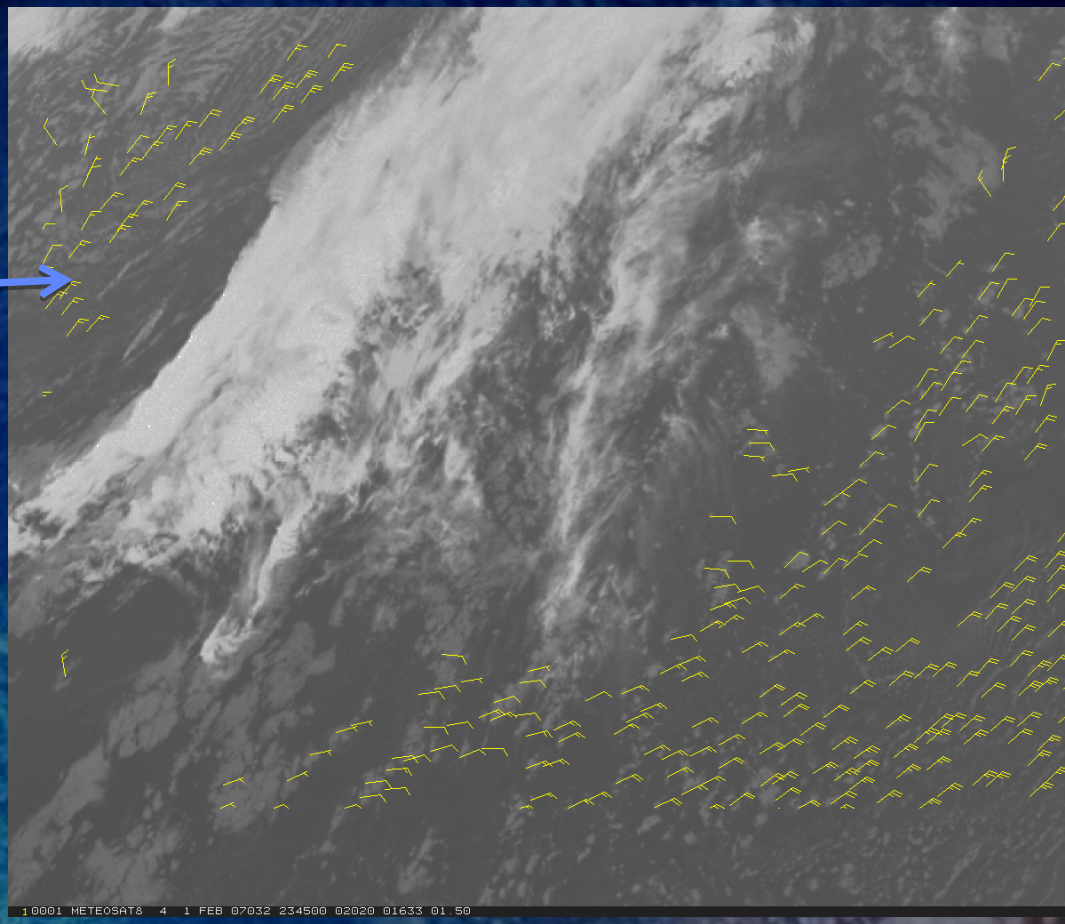
Low-Level >700 mb

Example Output

Short-wave IR Cloud-drift Winds

Cloud-drift Winds derived from a Full Disk Meteosat-8 SEVERI 3.9μm image triplet centered at 0000 UTC 02 February 2007



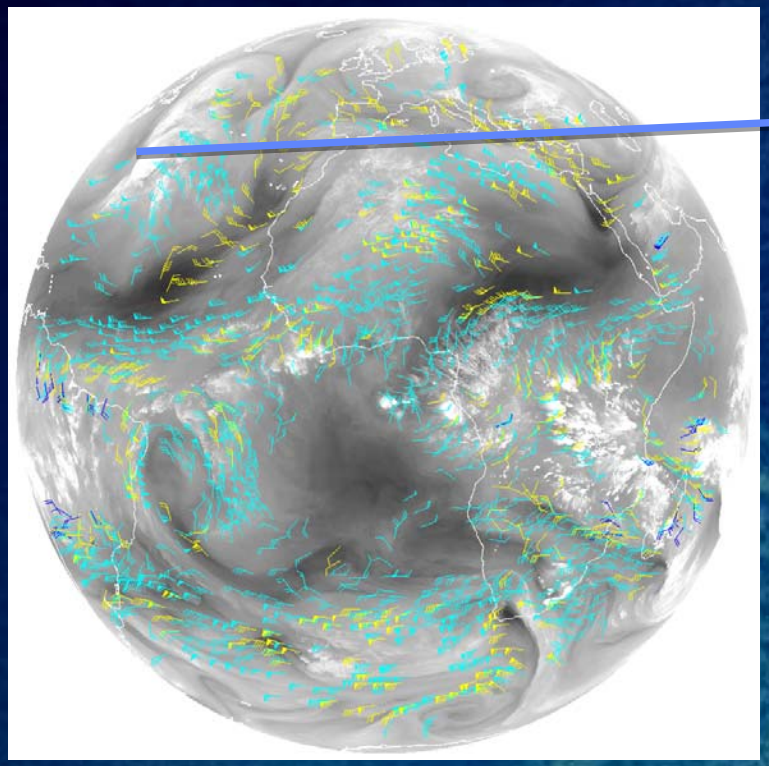


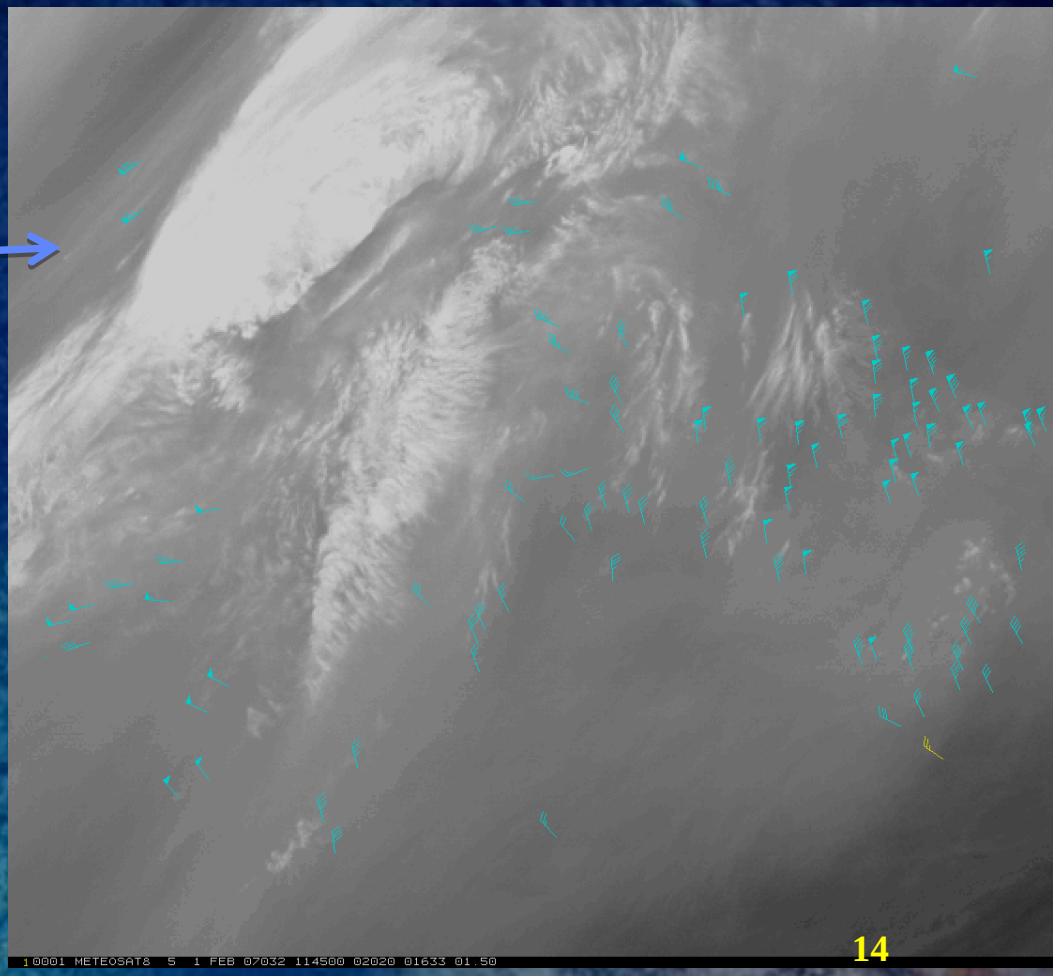
Low-Level >700 mb

Example Output

Clear-Sky Water Vapor Winds

Clear-sky Water Vapor Winds derived from Full Disk Meteosat-8 SEVERI 6.2um and 7.3um image triplets centered at 1200 UTC 01 February 2007



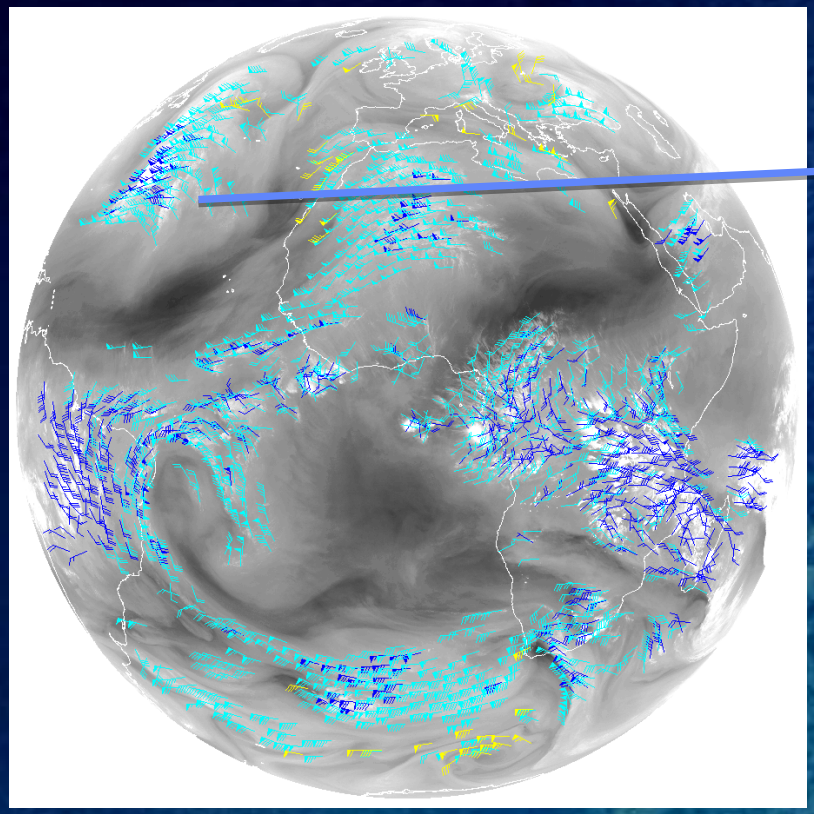


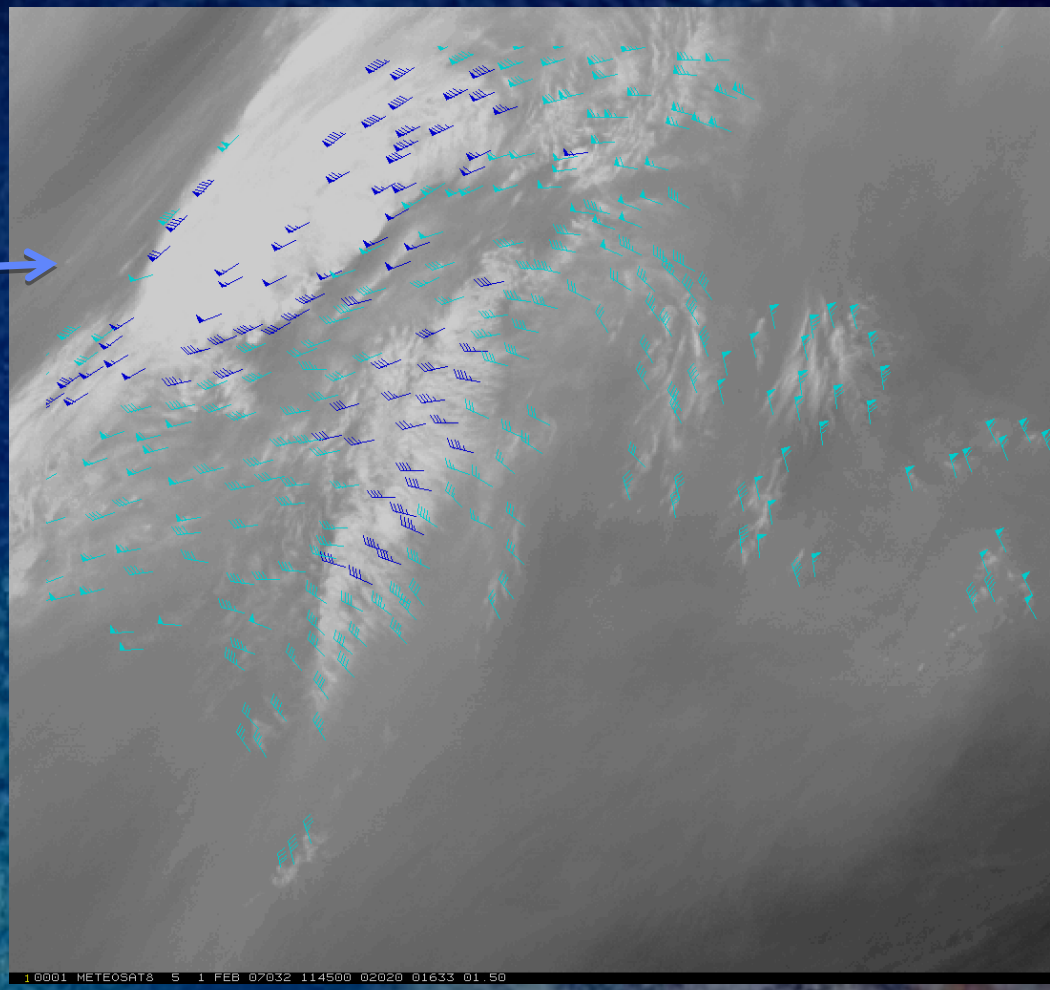
100-400 mb | 250-350 mb | 350-550 mb

Example Output

Cloud-top Water Vapor Winds

Cloud-top Water Vapor Winds derived from Full Disk Meteosat-8 SEVERI 6.2um image triplet centered at 1200 UTC 01 February 2007





100-400 mb

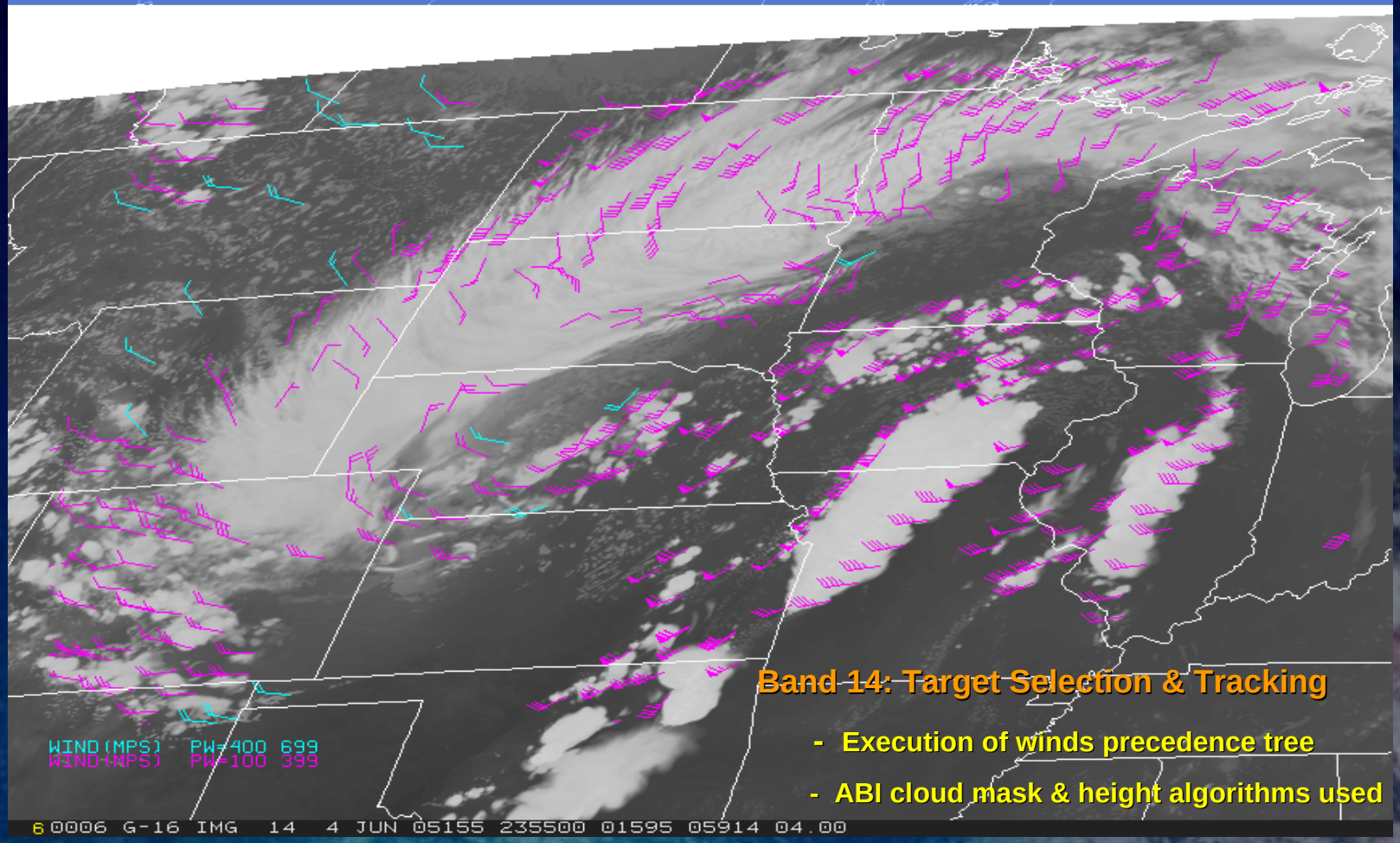
250-350 mb

350-550 mb

Example Output

Winds derived from simulated 11.2um imagery…

LWIR Cloud-drift AMVs derived from a Simulated GOES-R ABI image (Band 14; 11.2um) triplet centered at 0000Z on 05 June 2005



Band 14: Target Selection & Tracking

- Execution of winds precedence tree
- ABI cloud mask & height algorithms used

Algorithm Changes from 80% to 100%

- Added nested tracking as part of feature tracking algorithm *(Significant change)*
  - » Uses smaller target scenes “nested” within a larger target scene to derive local motions
  - » A clustering analysis algorithm is used to extract the dominant motion in the larger target scene
  - » Cloud-top products from pixels belonging to the largest cluster are used to assign a representative height to the derived motion wind
  - » Significant gains in product accuracy, particularly for upper -level LWIR cloud-drift winds.
  - » Near elimination of observed slow speed bias of satellite winds; *a significant concern of the NWP user community*

- Added use of the upper level water vapor 6.2um band to track cloud-top target scenes (ie., cloud-top WV winds)

Come visit our Winds Poster to learn more details about the nested tracking algorithm

Algorithm Changes from 80% to 100% *(cont'd)*

- Determined optimal settings to use for temporal interval and target box size for each band used to derive winds

- Modifications made to the SSD algorithm to reduce the processing time of the derived motion winds algorithm *(achieved a 25% reduction in processing time)*
  - » "Spiral search"
  - » Terminating SSD calculations once a minimum value has been exceeded

- Added detailed QC codes

- Inclusion and use of Expected Error (EE) thresholds that impact determination of final/overall product quality flag

- Metadata output added

ADEB and IV&V Response Summary

- All ATBD errors and clarification requests have been addressed
  - » We are developing a validation tool that uses CALIPSO data to assess and quantify derived motion wind height assignment errors
- No feedback required substantive modifications to the derived motion winds algorithm approach.

Validation Approach

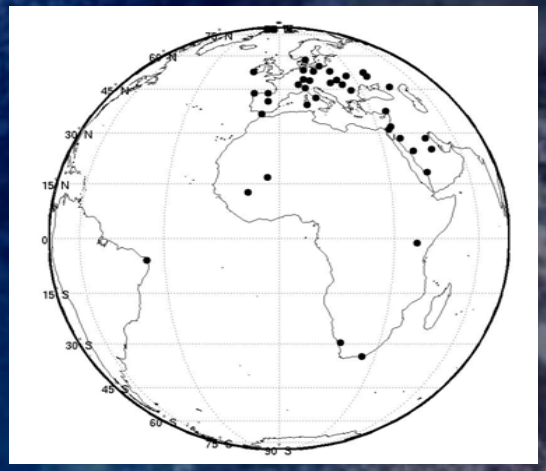
Validation Strategy

- Derive winds using GOES-R ABI proxy datasets
  - » Meteosat-8 SEVIRI
    - – Full-Disk data (Aug 2006; Feb 2007)
    - – Rapid-Scan data (June 1-8, 2008)
- Derive winds with full product precedence in place
    - – ABI Cloud Mask algorithm
    - – ABI Cloud-Top Pressure & Temperature
- Collocate (in space and time) derived satellite winds with reference ("truth") winds
  - » Winds derived from Meteosat-8 SEVIRI imagery and radiosonde wind observations (Land)
  - » Winds derived from Meteosat-8 SEVIRI imagery and GFS analysis winds (Ocean)
- Generate comparative statistics (Satellite winds – Reference Winds)
  - » Accuracy
  - » Precision

Validation Approach
Reference Data…

- Radiosonde wind observations serve as a key validation data source for derived motion wind products
  - » Used by all operational satellite processing centers that generate satellite derived motion winds (per CGMS standards defined by the International Winds Working Group)

- GFS Model Analysis Wind Fields
  - Validation tool development in progress



Radiosonde stations within MSG/SEVIRI domain

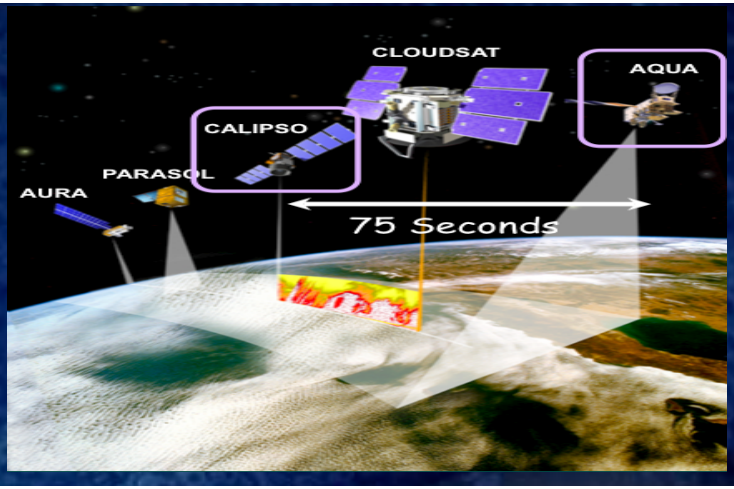
Validation Approach

For satellite wind height assignments…

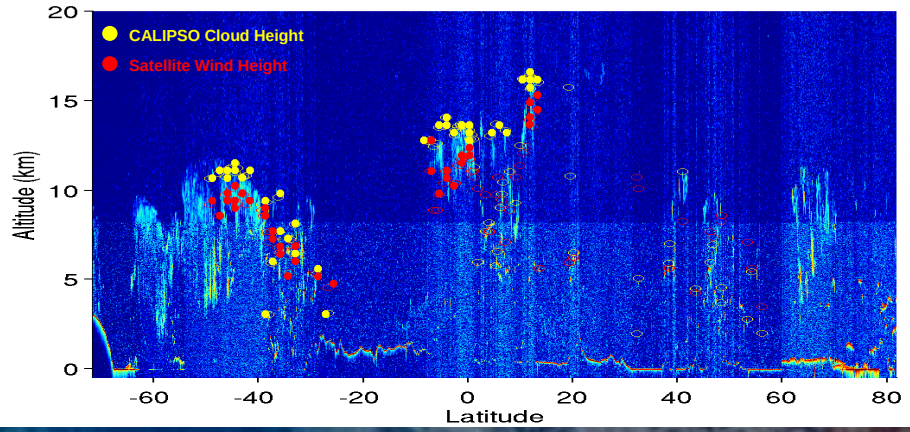
Using CALIPSO/CloudSat Data to Validate Satellite Wind Height Assignments

- Leverages unprecedented cloud information offered by CALIPSO and CloudSat measurements
- Enables improved error characterization of satellite wind height assignments
- Enables feedback for potential improvements to satellite wind height assignments
- Improvements to overall accuracy of satellite-derived winds

Work in progress…



GOES-12 Cloud-drift Wind Heights Overlaid on CALIPSO total attenuated backscatter image at 532nm

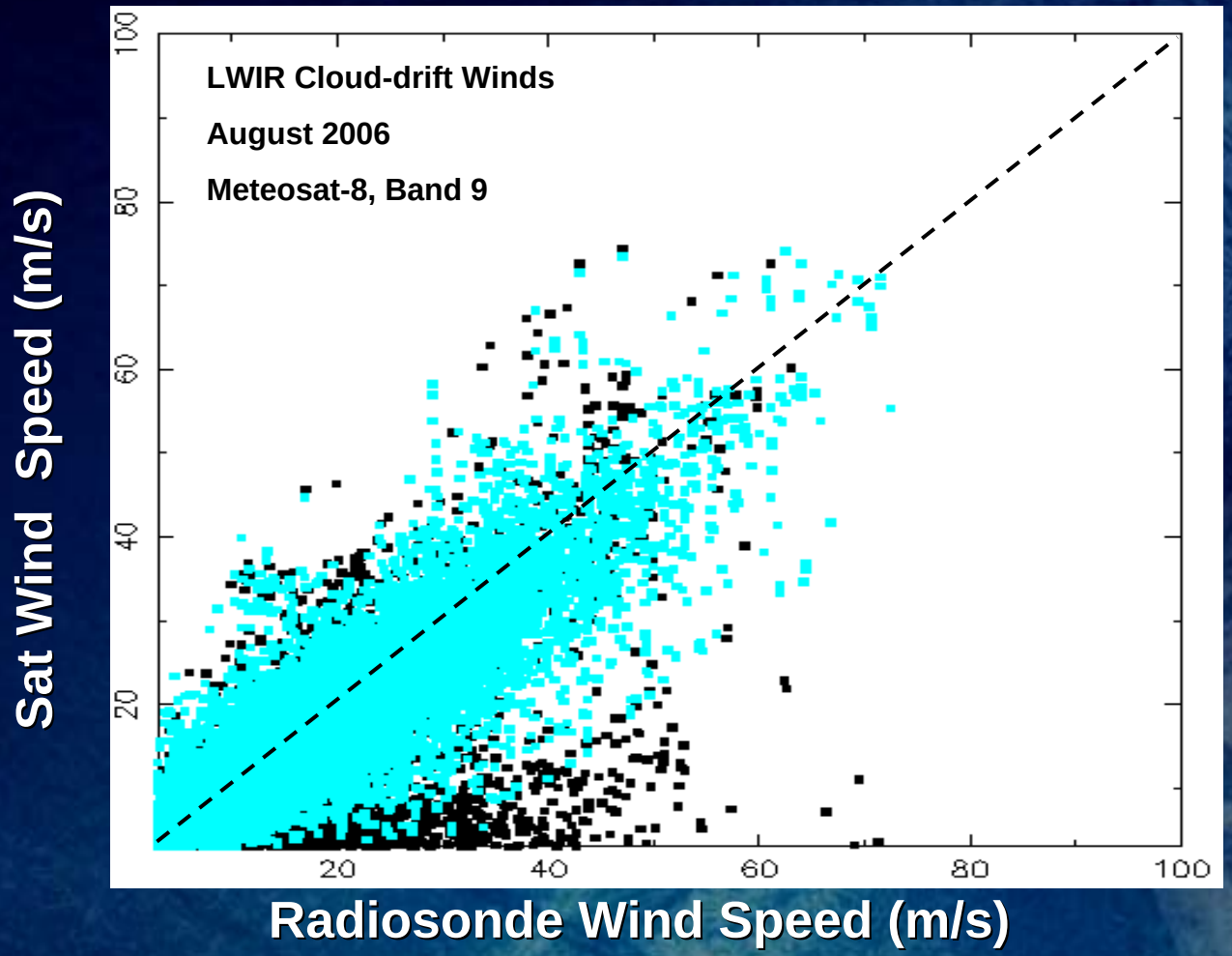


Validation Results

Validation Results

Version 3 vs. Version 4 Performance…

Version 4 algorithm winds are better fit to radiosonde



Black – Version 3 Algorithm

RMS:	7.78 m/s
MVD:	6.14 m/s
Spd Bias:	-2.00 m/s
Speed:	17.68 m/s
Sample:	17,362

Light Blue – Version 4 Algorithm (Nested Tracking)

RMS:	6.89 m/s
MVD:	5.46 m/s
Spd Bias:	-0.18 m/s
Speed:	17.91 m/s
Sample:	17,428

Validation Summary

	Derived Motion Winds vs. Radiosondes *August 2006, February 2007*	
High Level *(100-400 mb)*	**Accuracy (m/s)**	**5.93** (7.5)
	Precision (m/s)	**4.44** (4.5)
	Sample Size	**38170**
Mid Level *(400-700 mb)*	**Accuracy (m/s)**	**5.06** (7.5)
	Precision (m/s)	**3.83** (4.5)
	Sample Size	**11312**
Low Level *(> 700 mb)*	**Accuracy (m/s)**	**3.53** (7.5)
	Precision (m/s)	**2.60** (4.5)
	Sample Size	**15961**

- **Includes winds derived from all bands**
- **Satellite winds have a Quality Index score >= 60**

Validation Summary

Derived Motion Winds vs. Radiosondes *Met-8 SEVIRI; August 2006, February 2007*	
Accuracy (m/s)	**5.20** (7.5)
Precision (m/s)	**4.09** (4.5)
Sample Size	**65603**

- **Includes winds derived from all bands and at all levels**
- **Satellite winds have a Quality Index score >= 60**

Validation Summary

	Derived Motion Winds vs. GFS Analysis Met-8 SEVIRI	
Aug 31, 2006 (00Z)	Accuracy (m/s)	**3.73** (7.5)
	Precision (m/s)	**2.82** (4.5)
	Sample Size	**24472**
Feb 2, 2007 (12Z)	Accuracy (m/s)	**4.62** (7.5)
	Precision (m/s)	**3.31** (4.5)
	Sample Size	**24050**

- Includes winds derived from all bands
- Satellite winds have a Quality Index score >= 60

Summary

- The GOES-R ABI derived motion algorithm provides satellite derived winds by tracking cloud and clear-sky moisture features from a sequence of images.
- The derived motion wind product (Version 4) is meeting the F&PS specifications at the 100% level.
- Version 5 code and the 100% ATBD will be delivered soon.
- Validation tool development is continuing