DEVELOPMENT, VALIDATION, AND APPLICATIONS OF A MESOSCALE AMV PRODUCT AT UW-CIMSS

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Introduction and Motivations

• **In situations with complex mesoscale flows, vectors that accurately depict the conditions present at the smallest scales can be rejected by operational AMV QC because the satellite flow greatly deviates from the often coarse horizontal resolution background analysis.**

• **Bedka and Mecikalski (JAM, 2005) introduced a new AMV processing methodology that extends the current UW-CIMSS automated AMV algorithm toward depiction of mesoscale flows and their local variability**

- The mesoscale AMV methodology was developed to track cloud and water vapor (WV) motions associated with convective clouds in VIS, IR, and WV imagery

- This work represents one of many attempts (Fujita, Rabin at al, Hasler et al, and others) to objectively extract mesoscale flow information from satellite

• **Bedka and Mecikalski demonstrated these mesoscale AMVs within an algorithm that computes cumulus cloud growth rates, but did not quantitatively assess their relative accuracy**

Introduction and Motivations *(continued)*

• Although the mesoscale AMV fields appear reasonable and have been found useful to convection nowcasting applications, it is important to quantify their accuracy relative to operational AMVs and reliable ground-based wind measurements

The primary objectives of this presentation are to:

1)Describe the potential application of experimental GOES mesoscale AMVs toward weather diagnosis and forecasting

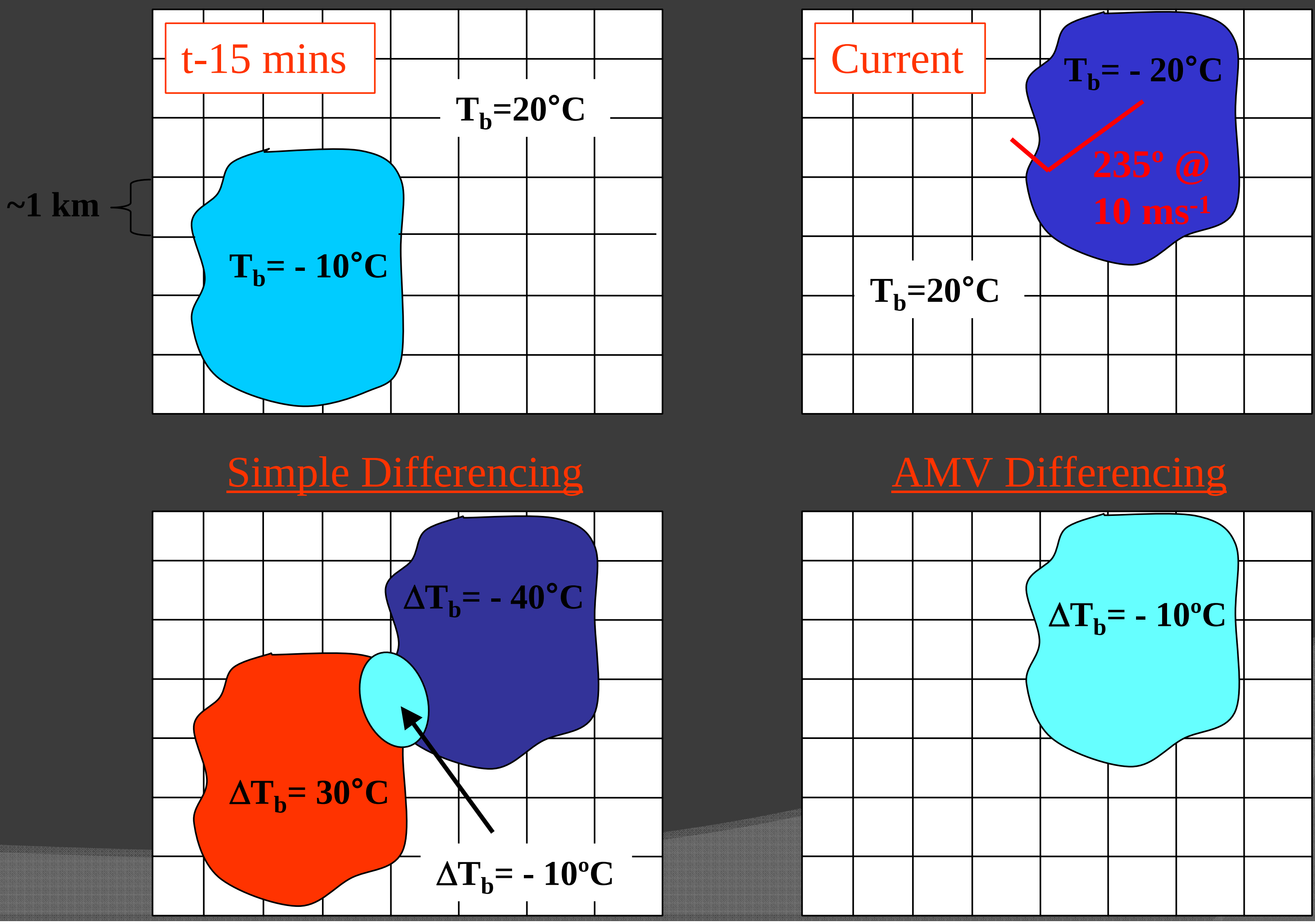
1)Compare the coverage and accuracy of mesoscale AMVs (MESO) to the NOAA/NESDIS operational AMV (OPER) product, relative to 6-minute NOAA Wind Profiler Network observations

1)Discuss National Weather Service experiences with MESO, and current/future plans for uses of AMVs in aviation weather hazard diagnosis and nowcasting

Cumulus Cloud-Top Cooling Rates Using AMVs

$U = 10\ ms^{-1}$ $u = U * \cos(\theta) = 7.07\ ms^{-1}$ $\Delta pixel\_x = (u*(\Delta t))/\Delta x$ =~6 pixels

$v = U * \sin(\theta) = 7.07\ ms^{-1}$ $\Delta pixel\_y = (v*(\Delta t))/\Delta y$ =~6 pixels



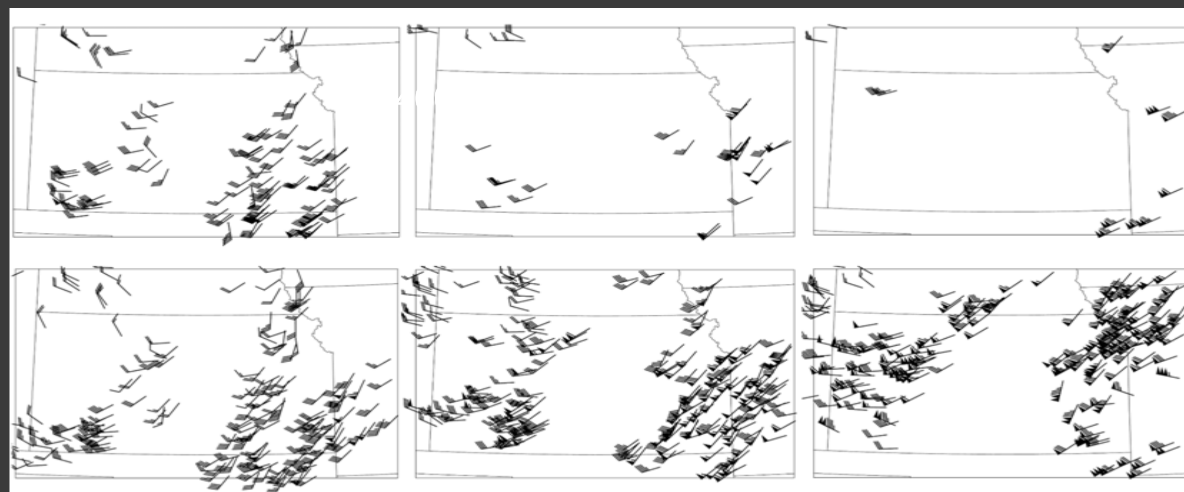
MESO have been used to identify the past locations of cumulus cloud pixels without concern for AMV accuracy relative to a ground-based truth wind measurement

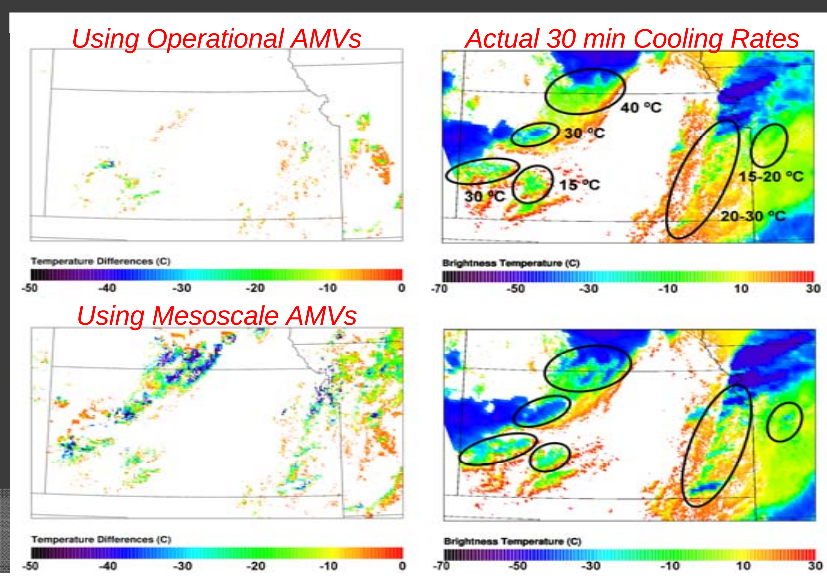
- A convective cloud mask is used to verify whether a predicted past pixel location contains a cumulus, reducing the impact of grossly errant AMVs that could induce false alarms in this cloud top cooling rate product

1000-701 hPa | 700-401 hPa | 400-100 hPa

AMVs Using Operational Settings (152 vectors)

Mesoscale AMVs (only 20% shown, 703 out of 3516 total vectors)





Bedka and Mecikalski (JAM, 2005)

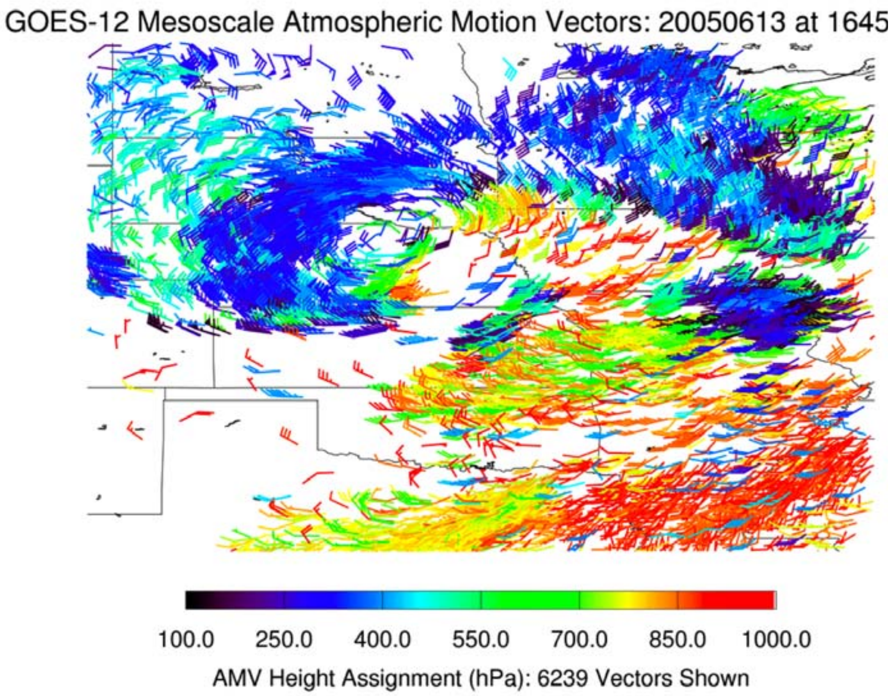
Primary Differences Between OPER and MESO Processing

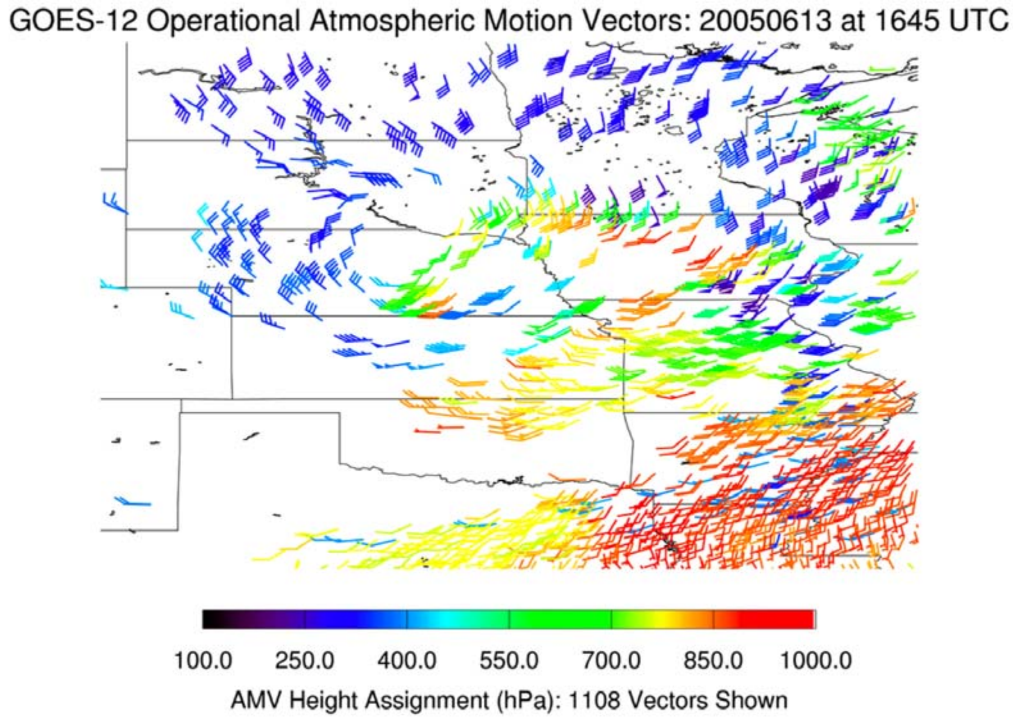
• **Adjustments to UW-CIMSS real-time AMV algorithm processing settings for the MESO product include:**

1) Smaller target box sizes
2) Visible pixel tracking up to the 100 hPa level
3) Removal of the NWP forecast check in the QI analysis
4) Removal of gross speed and directional checks against NWP
5) Increased maximum IR window channel target temperature
    - Increases the number of vectors from small cumulus clouds

AMV Algorithm Parameter	MESO Setting	OPER Setting
Target Box Size	5x5 Pixels (~5 km^2 for VIS and ~20 km^2 for IR and WV)	15x15 pixels (~15 km^2 for VIS and ~60 km^2 for IR and WV)
Visible AMV Height Range	1000-100 hPa	1000-600 hPa
Minimum Allowed RFF Analysis Score	0.01	0.50
Minimum Allowed QI Score	0.50	0.60
Gross Speed and Directional Comparison to NWP Forecast	NO	YES
Maximum IR Window Target Temperature	285 K	250 K

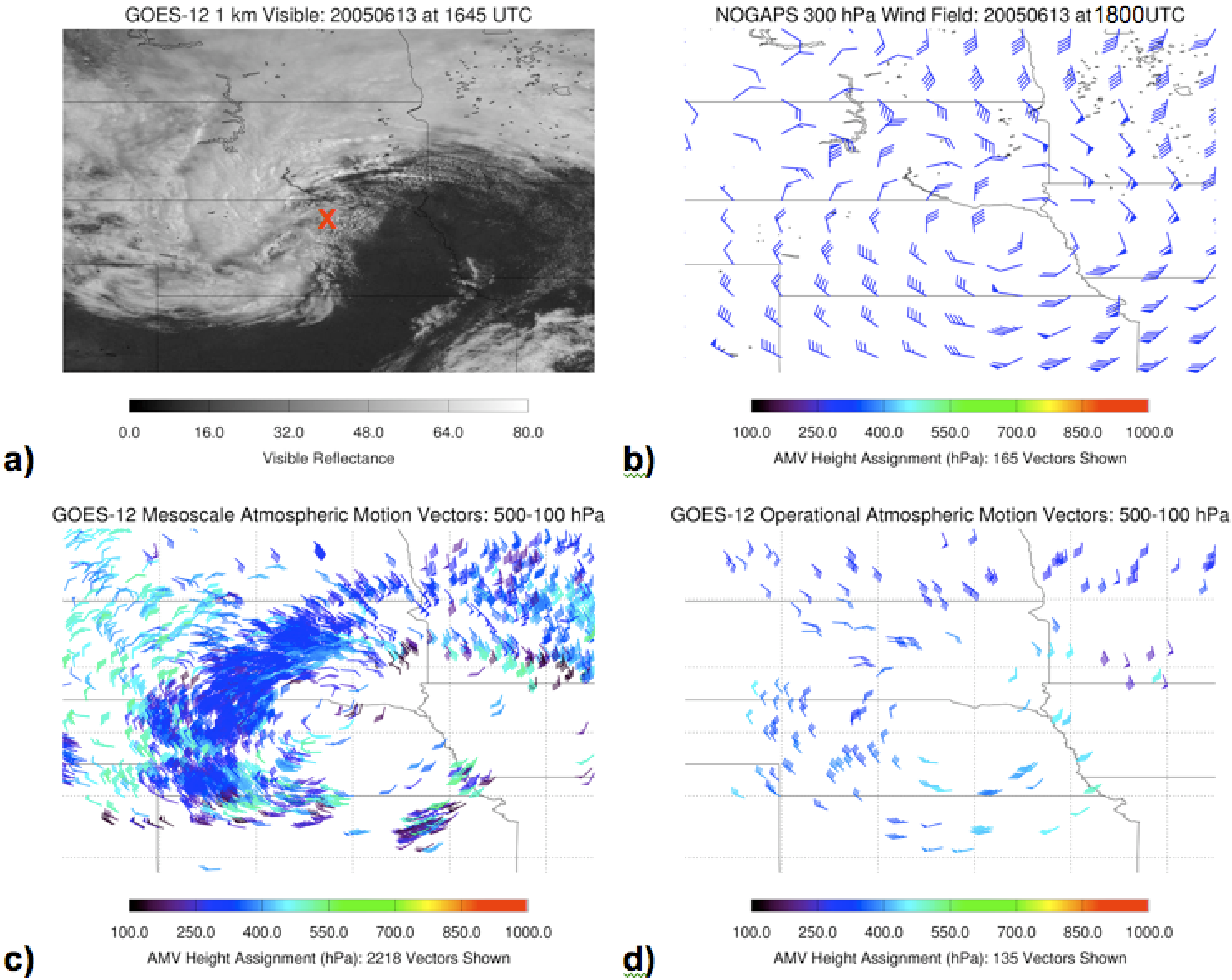
Detection of Mesoscale Flow Patterns (continued)

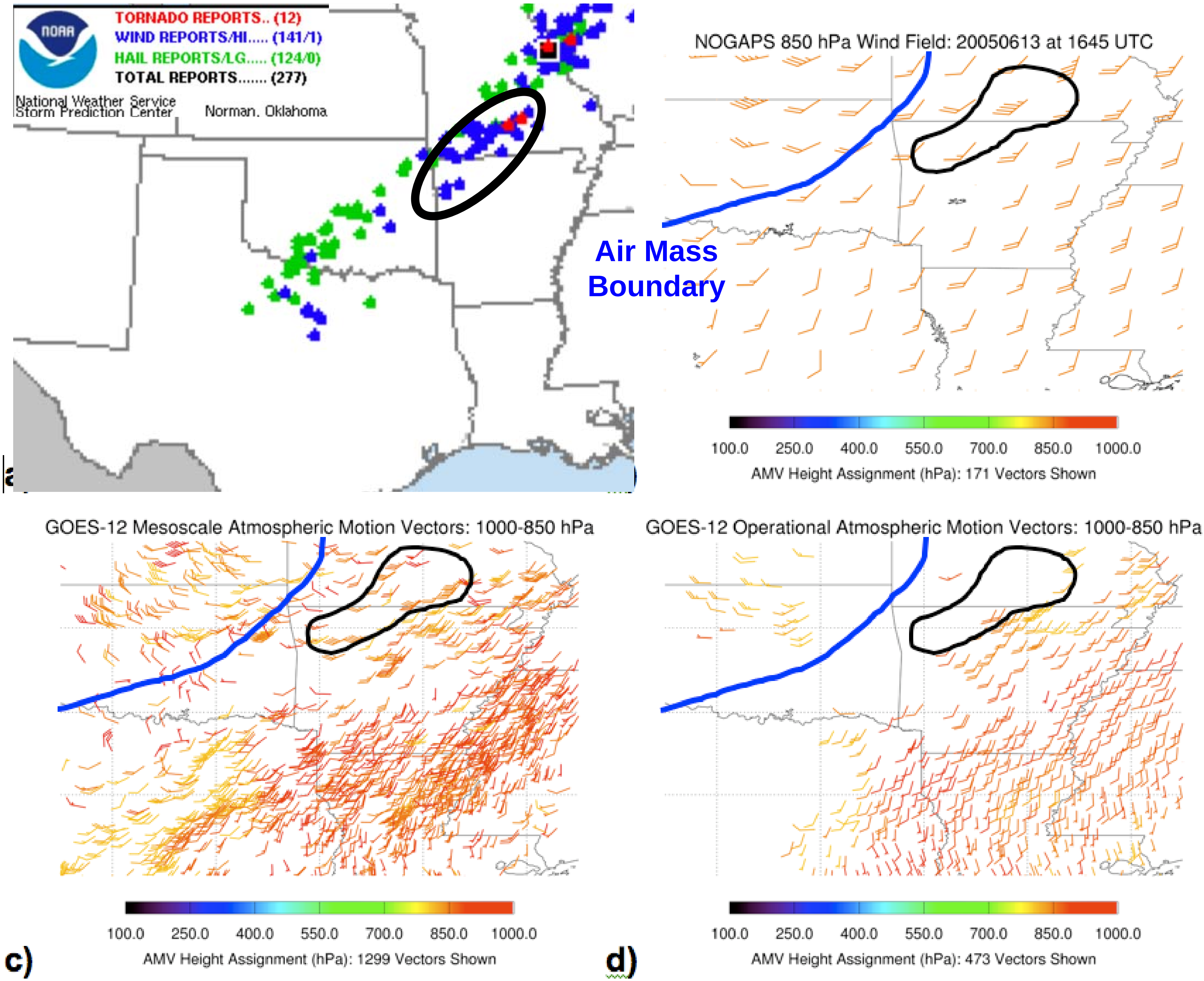




Here the MESO product better depicts:

1)The circulation center of a mid-latitude cyclone
2)Boundary layer confluence patterns
3)A narrow low-level jet that is well correlated with subsequent severe thunderstorm development

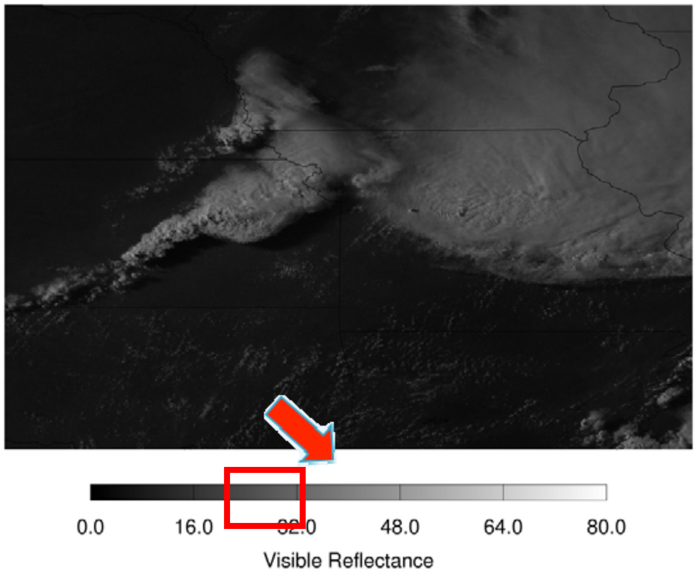

GOES-12 1 km Visible: 20050613 at 1645 UTC
0.0
16.0
32.0
48.0
64.0
80.0
Visible Reflectance
a)
NOGAPS 300 hPa Wind Field: 20050613 at 1800UTC
100.0
250.0
400.0
550.0
700.0
850.0
1000.0
AMV Height Assignment (hPa): 165 Vectors Shown
b)
GOES-12 Mesoscale Atmospheric Motion Vectors: 500-100 hPa
100.0
250.0
400.0
550.0
700.0
850.0
1000.0
AMV Height Assignment (hPa): 2218 Vectors Shown
c)
GOES-12 Operational Atmospheric Motion Vectors: 500-100 hPa
100.0
250.0
400.0
550.0
700.0
850.0
1000.0
AMV Height Assignment (hPa): 135 Vectors Shown
d)

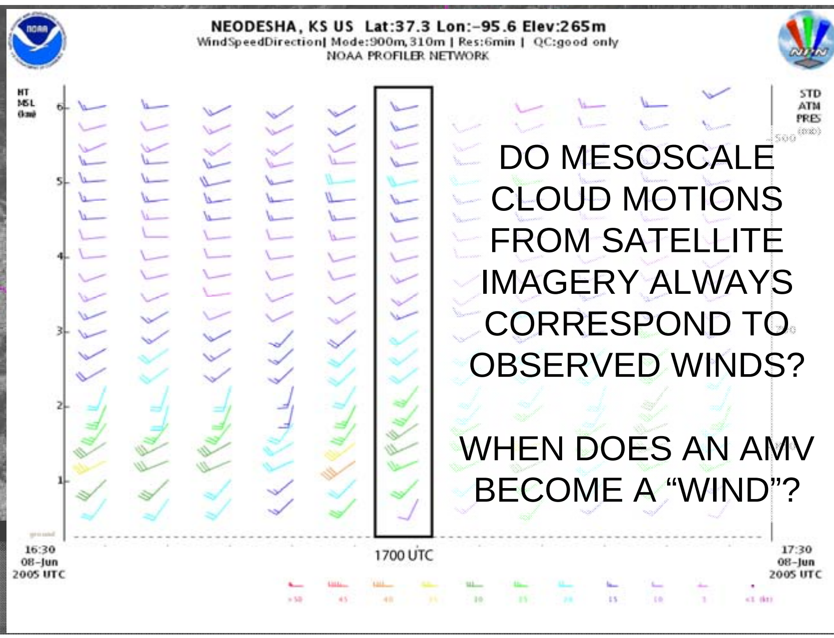


TORNADO REPORTS.. (12)
WIND REPORTS/HI..... (141/1)
HAIL REPORTS/LG..... (124/0)
TOTAL REPORTS....... (277)
National Weather Service
Storm Prediction Center
Norman, Oklahoma
Air Mass Boundary
NOGAPS 850 hPa Wind Field: 20050613 at 1645 UTC
100.0 250.0 400.0 550.0 700.0 850.0 1000.0
AMV Height Assignment (hPa): 171 Vectors Shown
GOES-12 Mesoscale Atmospheric Motion Vectors: 1000-850 hPa
100.0 250.0 400.0 550.0 700.0 850.0 1000.0
AMV Height Assignment (hPa): 1299 Vectors Shown
c)
GOES-12 Operational Atmospheric Motion Vectors: 1000-850 hPa
100.0 250.0 400.0 550.0 700.0 850.0 1000.0
AMV Height Assignment (hPa): 473 Vectors Shown
d)

Detection of Mesoscale Flow Patterns

GOES-12 1 km Visible: 20050608 at 2332 UTC

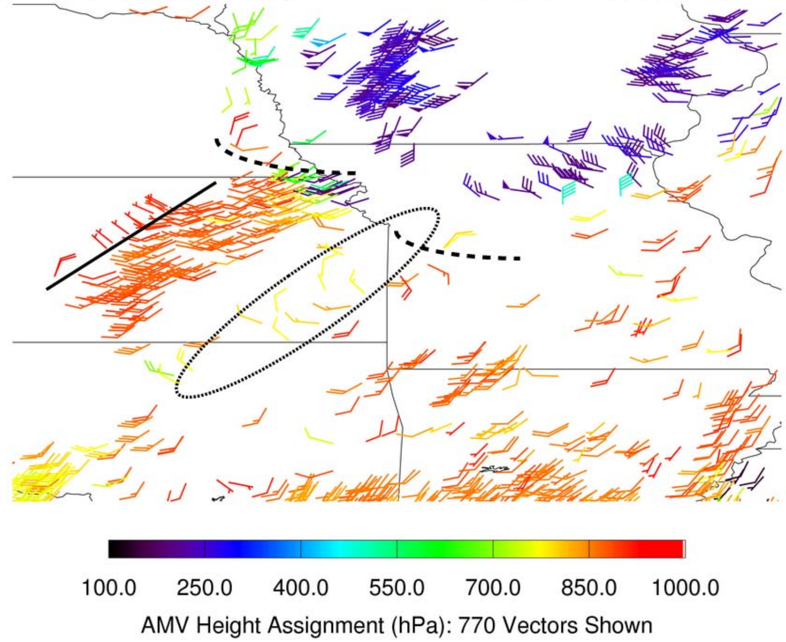




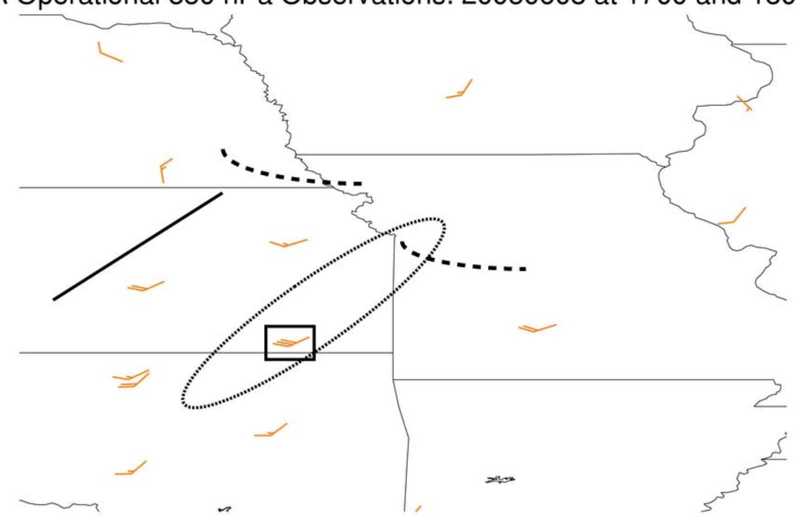
DO MESOSCALE CLOUD MOTIONS FROM SATELLITE IMAGERY ALWAYS CORRESPOND TO OBSERVED WINDS?

WHEN DOES AN AMV BECOME A "WIND"?

GOES-12 Mesoscale Atmospheric Motion Vectors: 20050608 at 1702 UTC



NOAA Operational 850 hPa Observations: 20050608 at 1700 and 1800 UTC



17 UTC Profiler + 18 UTC Sonde

MESO AMV Validation Study Information

- MESO and OPER are compared to NOAA wind profiler and rawinsonde over the Lamont, OK DOE ARM site for a one year period (April 2005-2006)

- Comparisons to wind profiler will be shown in the following slides

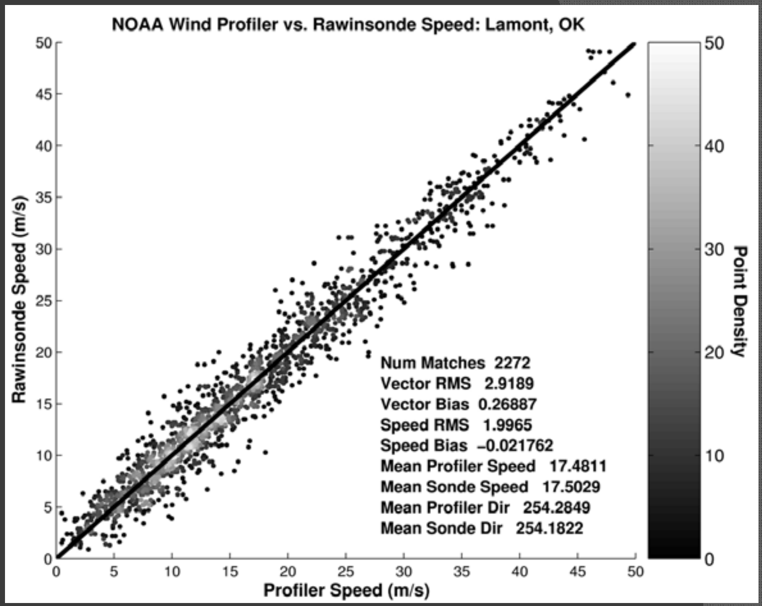
Datasets Compared	Number of Matches	Horizontal Match Criterion	Vertical Match Criterion	Temporal Match Criterion
Comparison 1: Co-located NOAA wind profiler, Rawinsonde, and MESO				
NOAA Wind Profiler to Rawinsonde	2272	25 km	2 hPa	+/- 3 mins
NOAA Wind Profiler to MESO	2272	25 km	10 hPa	30 min mean profiler data centered on AMV time
Rawinsonde to MESO	2272	25 km	2 hPa	Balloon launch within +/- 30 mins of MESO time
Comparison 2: Co-located NOAA Wind Profiler with MESO and OPER				
NOAA Wind Profiler to MESO	11832	25 km	10 hPa	30 min mean profiler data centered on AMV time
NOAA Wind Profiler to OPER	721	25 km	10 hPa	30 min mean profiler data centered on AMV time
Comparison 3: Direct Comparison Between MESO and OPER				
MESO to OPER	247	50 km	25 hPa	30 mins

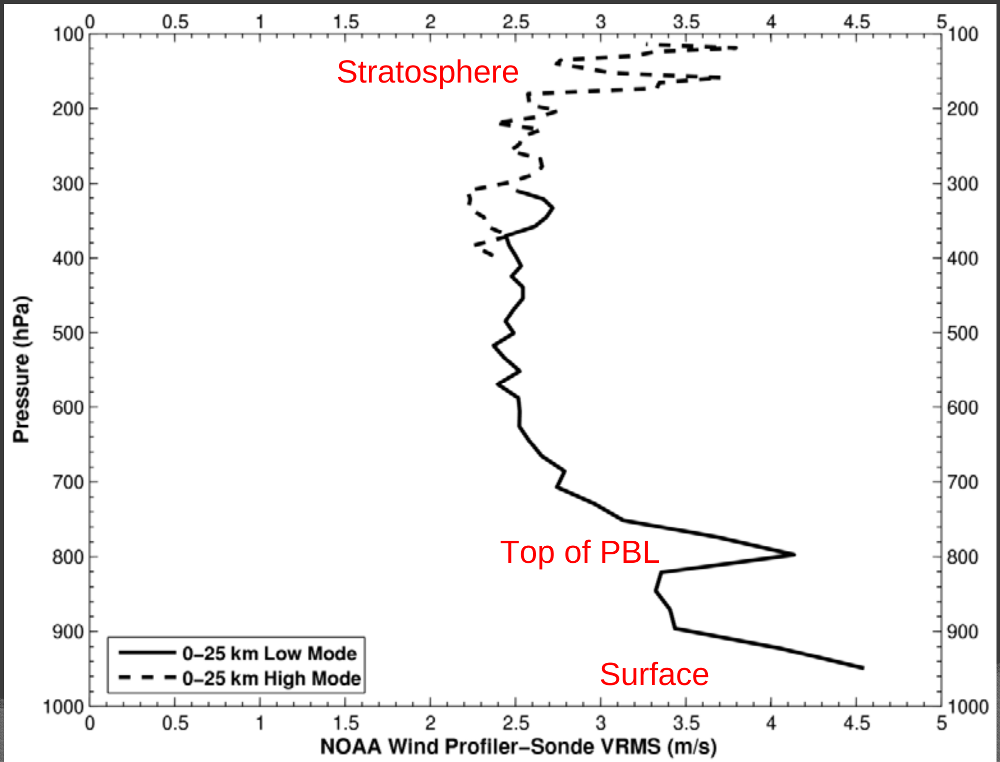
MESO AMV Validation paper: Bedka et al. (in review, JAM, 2008)

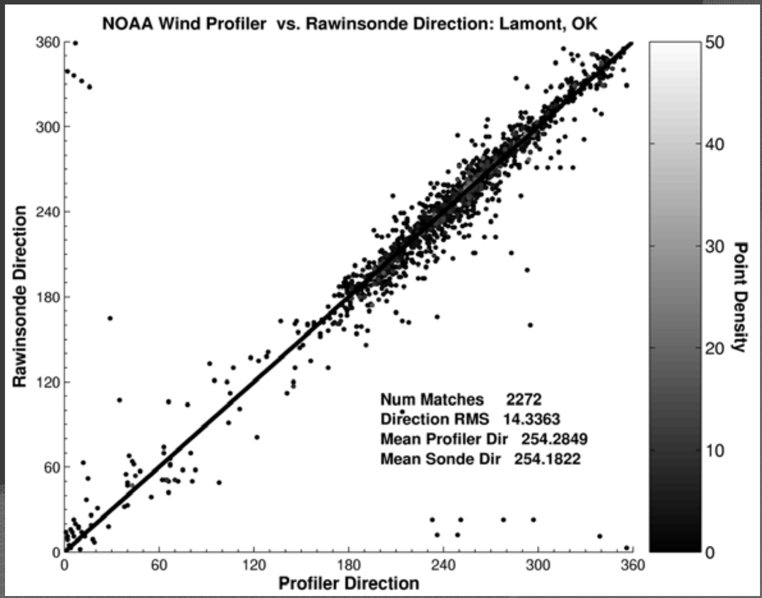
Use of 404 MHz Wind Profiler for AMV Validation

- Wind profiler observations agree well with co-located rawinsonde, especially within the 800-200 hPa layer

- Larger differences near the surface and PBL top could be induced by increased atmospheric variability and/or inadequate profiler vertical resolution (350 m) in regions where strong vertical wind shear is often present







AMV Validation Using 6-min Wind Profiler

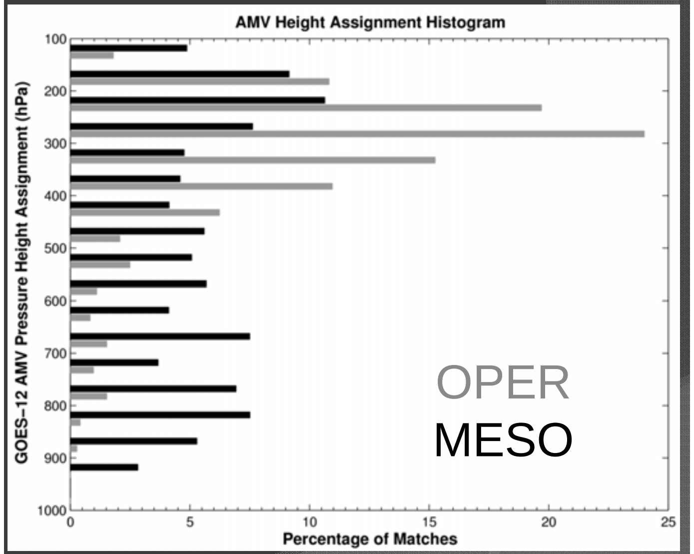
- The MESO product offers a significant increase in vector density and an even vertical vector distribution, while OPER provides improved relative accuracy with information being concentrated in the upper troposphere

- QI does provide a means for MESO vector quality control, though there is more room for improvement

- The largest MESO AMV-profiler vector differences were associated with thin cirrus, multi-layered clouds, and deep convective outflow

Comparison Type	Number of Vectors	Directional RMS (degrees)	Wind Speed Bias (ms^{-1})	Wind Speed RMS (ms^{-1})	Vector RMS (ms^{-1})
All MESO Vectors	11832	34.02	.48	5.78	8.50
All OPER Vectors	721	18.23	.89	4.12	5.56

Comparison Type	Number of Vectors	Directional RMS	Wind Speed Bias	Wind Speed RMS	Vector RMS
MESO AMV					
0.50 ≤ QI score < 0.75	6216	39.74	.17	5.95	8.98
0.75 ≤ QI score < 0.90	2625	30.79	.71	5.69	8.33
0.90 ≤ QI score	2991	25.40	.82	5.47	7.46
OPER AMV					
0.60 ≤ QI score < 0.75	105	29.07	.54	5.37	7.44
0.75 ≤ QI score < 0.90	120	14.13	.10	4.19	5.35
0.9 ≤ QI score	281	9.18	1.06	3.60	4.63

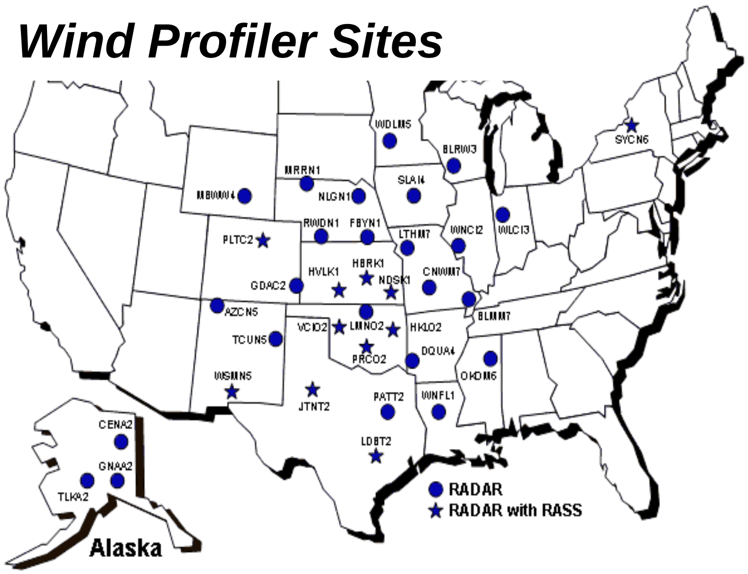


~80 % of MESO from the Visible channel

Upper Midwest NWS Forecaster Feedback on the Mesoscale AMV Product

Rawinsonde Launch Sites

Wind Profiler Sites



- **The MESO product has has been provided to U.S. National Weather Service (NWS) offices in the Upper Midwest since May 2007**

- **Forecasters have found the product useful for acquiring a detailed synopsis of the wind flow present at a given time**

Forecasters indicated:

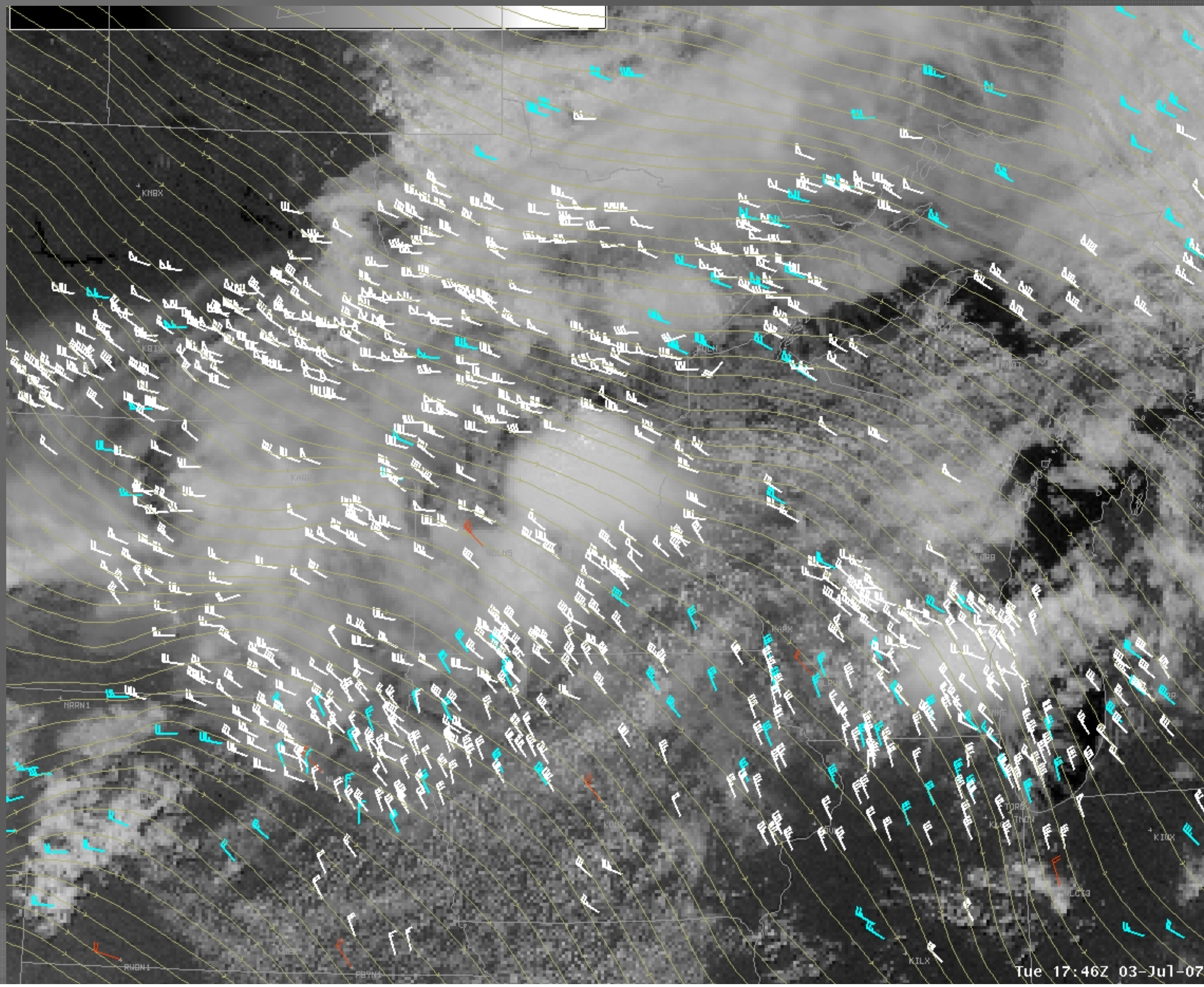
1)A preference for a fixed Eulerian wind observation (wind profiler) from which they can monitor the flow changes in time, rather than observations that move with the flow (i.e. AMVs)

2)A desire for a merged MESO AMV + NWP wind analysis and derived vorticity/divergence fields from the MESO product

- **The vast array of upstream data over the U.S. Upper Midwest (sonde, wind profiler, NWP) limited the overall usage of AMV fields in their operational forecast environment…may not apply to other regions/offices (i.e. Western U.S.)**

AMV Product Displays in the U.S. NWS AWIPS System

375-225 hPa Mesoscale (White) vs. Operational (Cyan) Winds



Applications of Mesoscale AMVs in Aviation Weather Hazard Nowcasting Systems

- **Satellite-based MESO AMV and convective storm initiation nowcasting products are being tested within the FAA-supported Consolidated Storm Prediction for Aviation (CoSPA) system**

- **Plans for MESO AMV usage within the CoSPA system include:**

1) Use AMVs to provide the track of predicted convective storms during convective initiation when radar-derived motions are not available (because the convection is in an emerging, pre-VIL state)

    - Issue: Cloud motion does not always equate to radar motion, so we need to determine how to properly weight AMVs relative to radar-derived motions from neighboring echoes and/or RUC NWP winds

2) Use AMVs to "buddy check" and potentially adjust radar-derived motions that are flagged as questionable

- **The MESO product will also be used as input within the FAA-supported Graphical Turbulence Guidance Nowcast (GTG-N) system, being developed at NCAR, to investigate the presence of aviation turbulence signals within AMV fields**

Conclusions

• **This work represents one of many attempts (Fujita, Rabin at al, Hasler et al, numerous others) to objectively extract mesoscale flow information from satellite**

- MESO settings may be modulating algorithm internal QC framework a bit too much, but removal of course resolution FG field impact is essential for mesoscale flow identification

- Some "happy medium" should be identified that balances mesoscale flow information/density and vector error

• **6-minute 404 MHz NOAA Wind Profiler observations represent a useful AMV validation dataset, especially within the 800-200 hPa layer**

- Atmospheric variability may be influencing validation stats at levels below this layer

• **A statistical comparison between AMV and NOAA Wind Profiler demonstrates that OPER exhibits closer agreement with these ground-based observations than MESO for all height layers and QI values**

Conclusions *(continued)*

• **A comparison between the MESO and OPER products for selected events shows that MESO better depicts the circulation center of a mid-latitude cyclone and boundary layer confluence patterns that were well correlated with future convective storm development**

- Examples show that the cross-correlation feature tracking algorithm is often very effective in capturing motions that can be seen in imagery with the human eye

- How do we objectively differentiate “motions” from “winds” at the mesoscale?

- While the individual MESO AMVs may sacrifice some absolute accuracy, these type of vectors show promise in providing greater temporal and spatial flow detail that can benefit diagnosis of upper-air flow patterns in near real-time

Future Work Suggestions

• **Evaluate the relative accuracy of and flows captured within MESO AMVs derived from 5 min rapid scan vs. 15 min imagery**

• **Develop QC methods designed to allow for ageostrophic mesoscale flows**

- Experiment with the use of high-resolution models (RUC, WRF?) as AMV algorithm background wind field

- Include cloud typing information to objectively identify potentially problematic scene types (semi-transparent cirrus, multi-layered clouds) for AMV algorithms

• **Develop vorticity and divergence products from MESO AMVs for evaluation by operational forecasters**

• **Once adequate mesoscale QC methods are developed, assimilate MESO AMVs in regional, high-resolution NWP model to evaluate potential benefits**