A Nested Tracking Approach for Reducing the Slow Speed Bias in Atmospheric Motion Vectors (AMVs)

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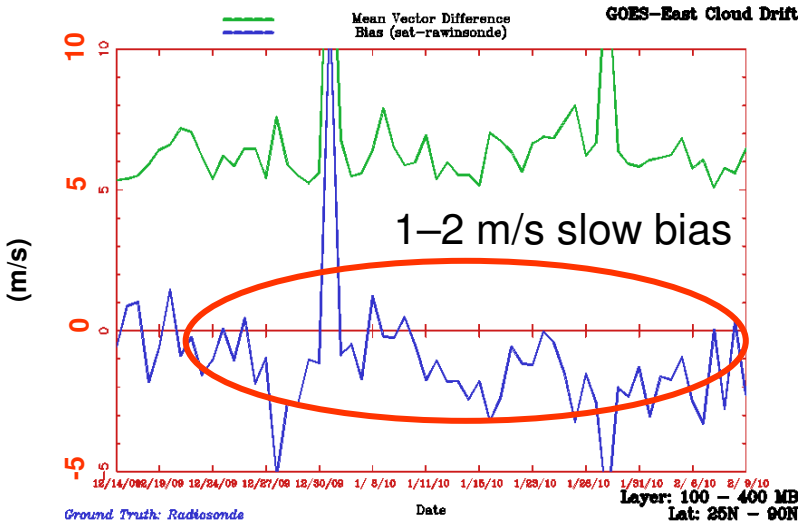
Topics

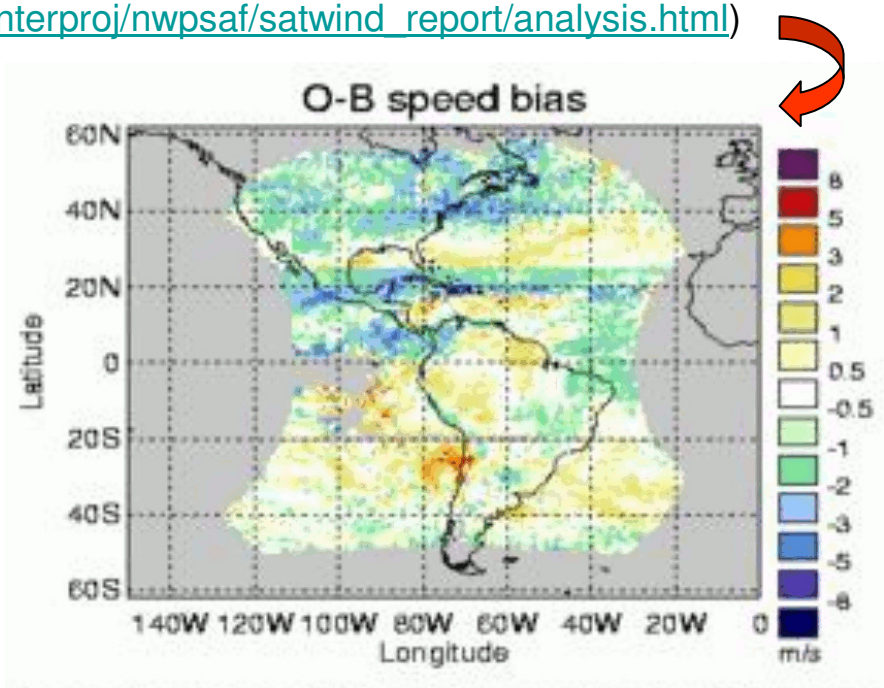
- **Description of Problem**
  - Slow speed bias at mid and upper levels – most pronounced in extratropics during the winter season
- **Impact of box size and time interval on magnitude of bias**
  - Influences height assignment and AMV speed
- **Nested tracking approach for reducing slow speed bias**
  - Replace an average or multi-layer motion with a local motion
  - Links tracking to height assignment
  - Addresses both issues
- **Results from Testing**
- **Summary, Future Plans, and Opportunities**

Note: This work is part of AMV algorithm development for the GOES-R ABI instrument

Description of Problem

- **Numerous studies have highlighted the slow speed bias problem**
  - See for example the NWP SAF web page maintained by the Met Office
  - (http://www.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/analysis.html)





- **Two leading causes include:**
  - Bad height (too high)
  - Derived motion is an average of motion at multiple levels and/or different scales

Impact of Box Size and Time Interval on Magnitude of Speed Bias

- Earlier studies by Sohn and Borde (2008) have shown a link between box size and magnitude of slow bias. Their results showed:
  1. A smaller box produces faster winds
  2. A smaller box produces lower heights

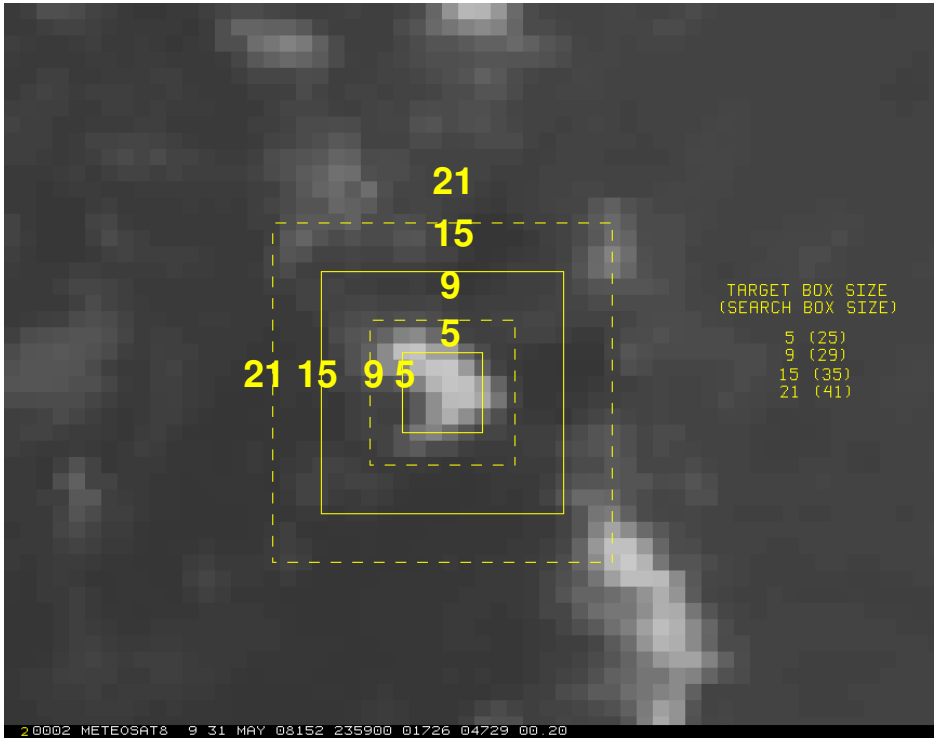
  Both factors reduce the slow bias!

- Above work was extended by present authors to include varying time intervals (5-, 10-, 15- and 30-minute intervals)

Impact of Box Size and Time Interval on Magnitude of Speed Bias

Setup of Study

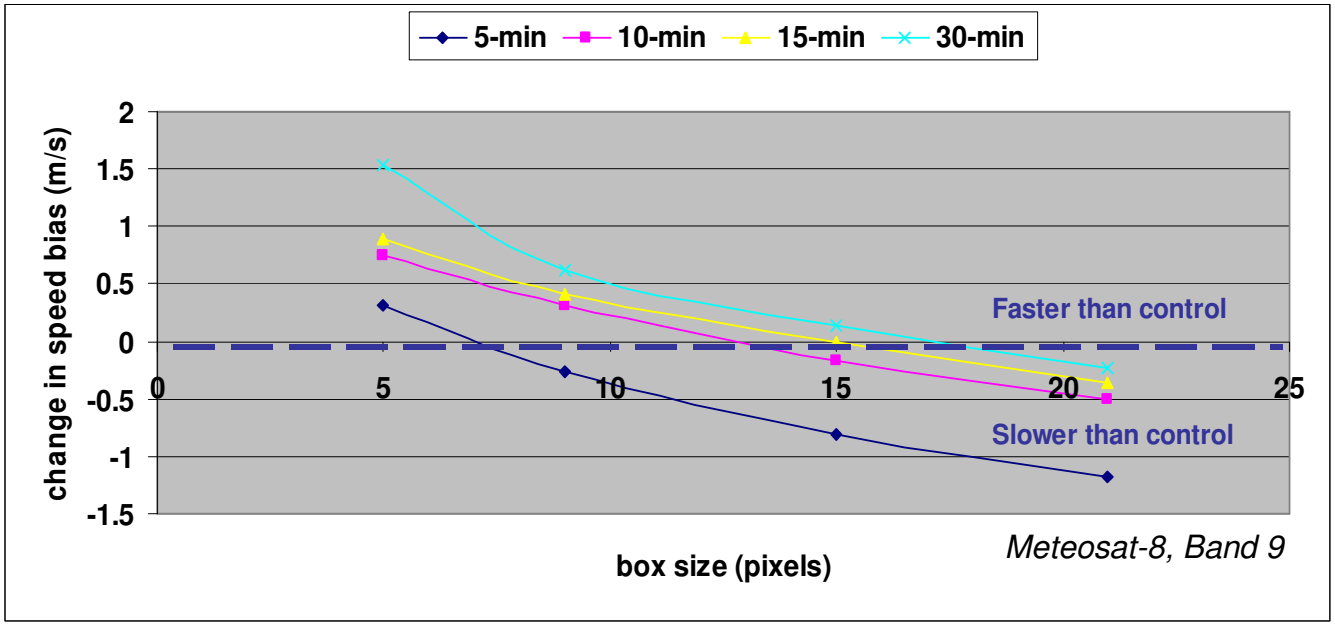
- Winds were generated using Meteosat-8 rapid scan imagery for the period June 1 – 8, 2008.
- Target locations were fixed while box size and time interval varied.



- **Target Box Size**
  - 5x5, 7x7, 9x9, 15x15, 21x21
- **Time Intervals:**
  - 5, 10, 15, 30 minutes

Impact of Box Size and Time Interval on Magnitude of the Speed Bias

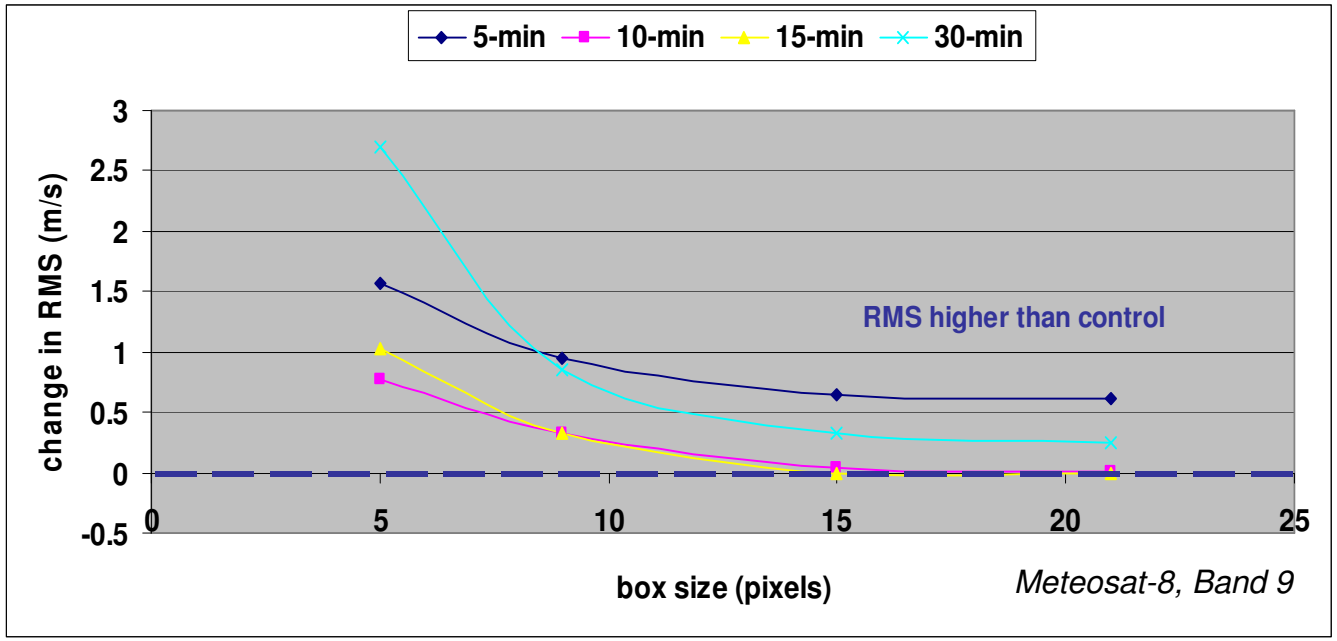
Results – *relative to control run (15x15 box, 15-minute loop interval)*



- A larger box yields a larger slow bias – consistent with Sohn and Borde (2008)
  - Argues for small box to reduce speed bias
- Larger time interval also reduces slow bias – new result

Impact of Box Size and Time Interval on the RMS

Results – relative to control run (15x15 box, 15-minute loop interval)



- A larger box reduces the RMS – largest box tested was 21x21 pixels
  - Argues against using a small box

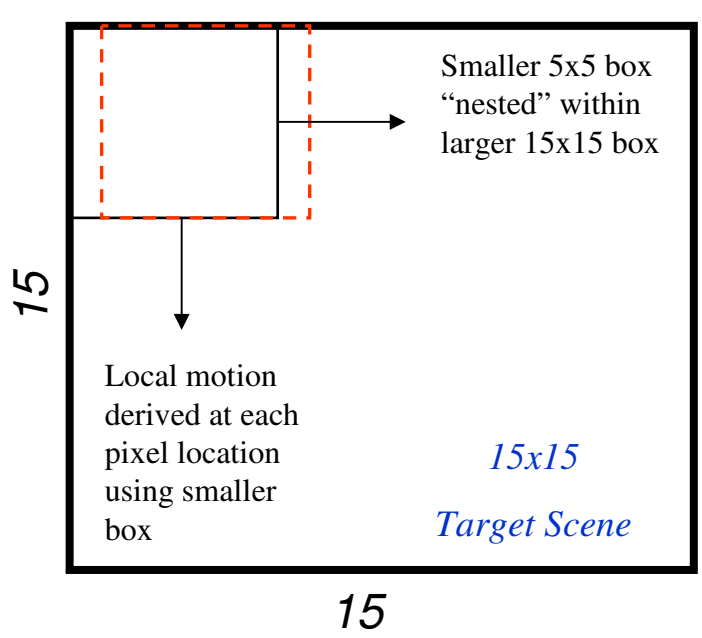
Nested Tracking Approach for Reducing Slow Speed Bias

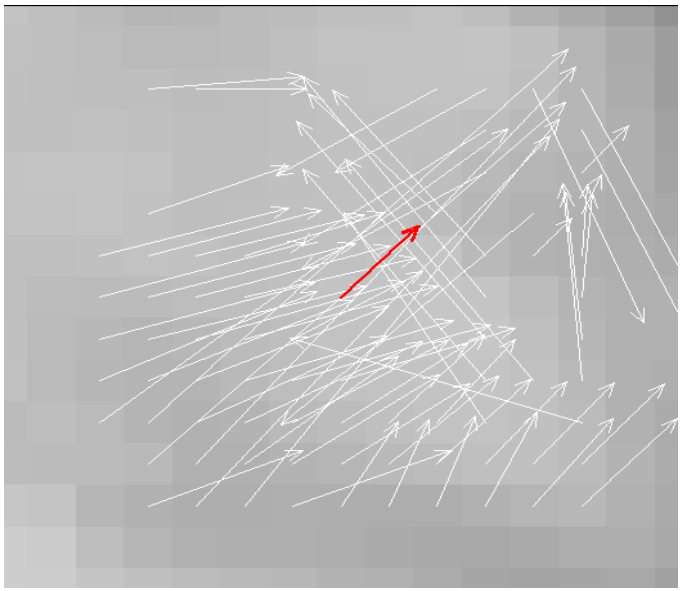
Challenge:

Use smallest box possible to retain fast wind speeds without increasing the RMS

Solution:

Use a small 5x5 box "nested" within larger box



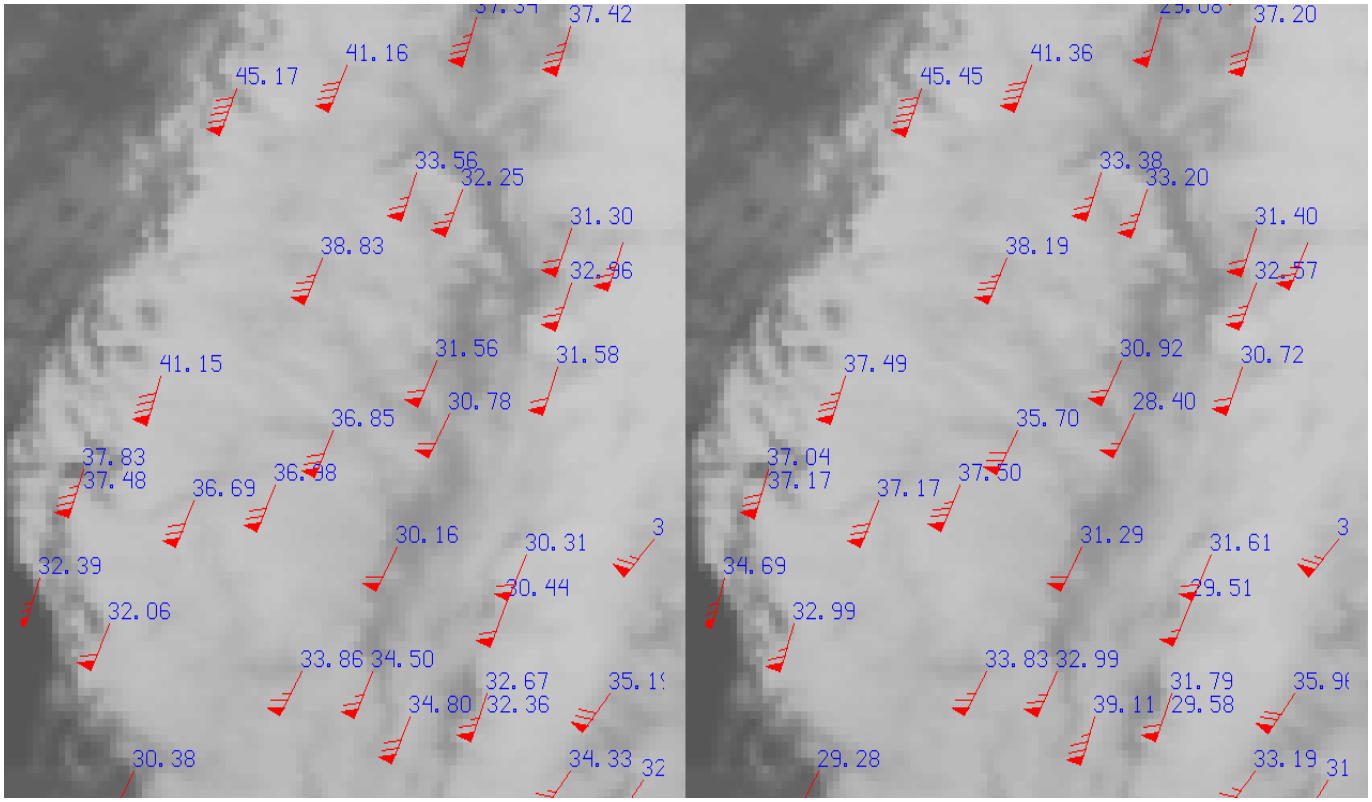


White arrows show local motion derived using 5x5 box centered at pixel location

Red arrow shows average of all white vectors

Nested Tracking Approach for Reducing Slow Speed Bias

How does the average motion of all the 5x5 AMV solutions compare to a single AMV solution derived from a 15x15 box?



- Note close agreement between the two vector fields.

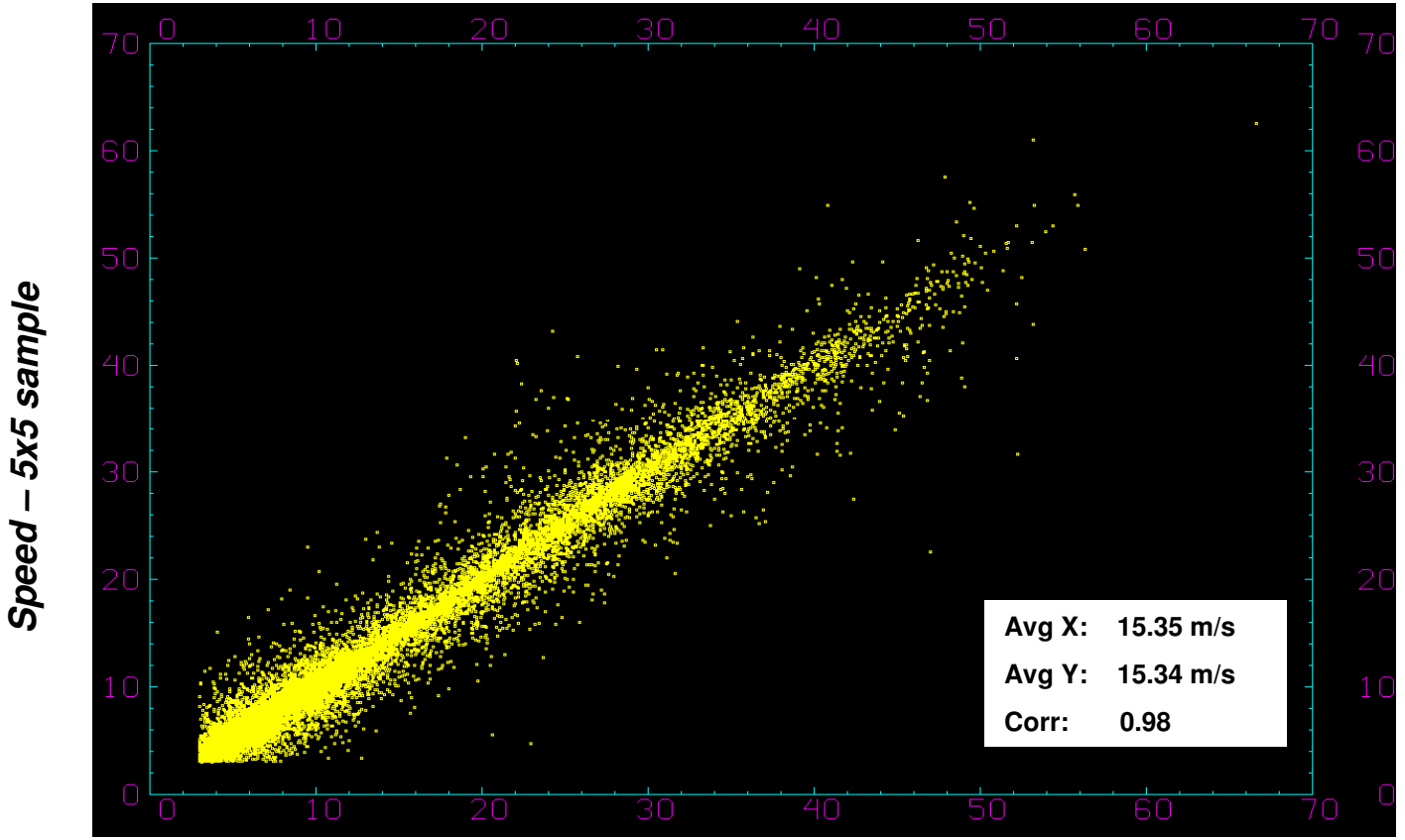
- Confirms that estimate from larger box is an *average of local motion*
  - From different levels
  - From different scales

00Z June 1, 2008

Meteosat-8, Band 9

Nested Tracking Approach for Reducing Slow Speed Bias

How does average speed of all the 5x5 AMV solutions compare to a single AMV speed derived from a 15x15 box?



12Z Feb 1, 2007

Meteosat-8, Band 9

Nested Tracking Approach for Reducing Slow Speed Bias

How can we use local motion vector field?

- Need to be able to separate noise from dominant motion
- Want to link pixels driving the tracking solution with the height assignment
  - Same goal as Borde and Oyama (2008), but different approach

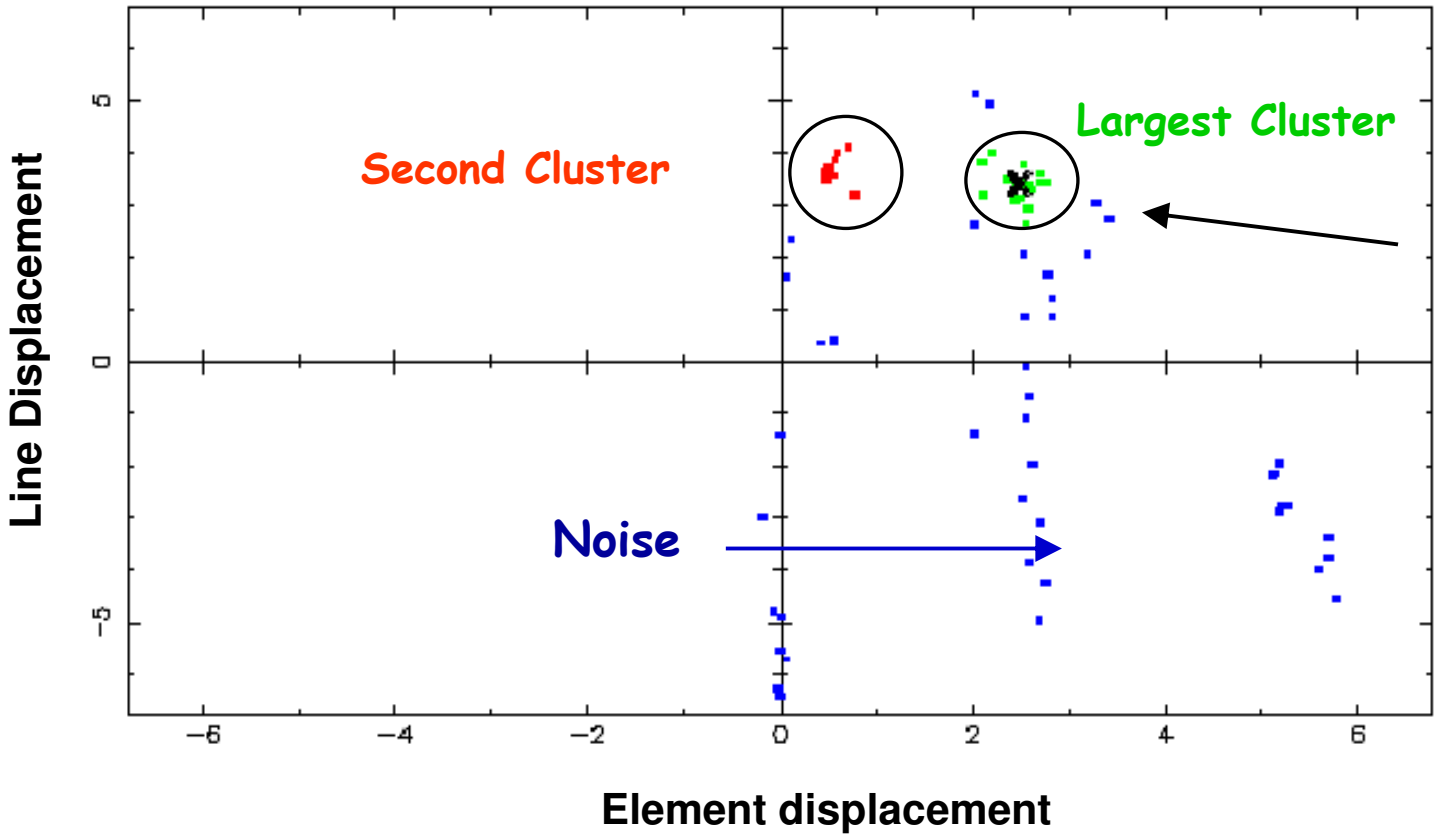
Cluster analysis of displacements is one way

- Use density-based cluster analysis called DBSCAN**
  - Locates regions of high density that are separated from one another by regions of low density
  - Very effective at identifying “noise”

**Ester, M., H.-P. Kriegel, J. Sander and X. Xu (1996): A Density-Based Algorithm for Discovering Clusters in Large Spatial Databases with Noise. In Proceedings of 2nd International Conference on Knowledge Discovery and Data Mining (KDD-96), Portland, Oregon, USA, 226-231

Nested Tracking Approach for Reducing Slow Speed Bias

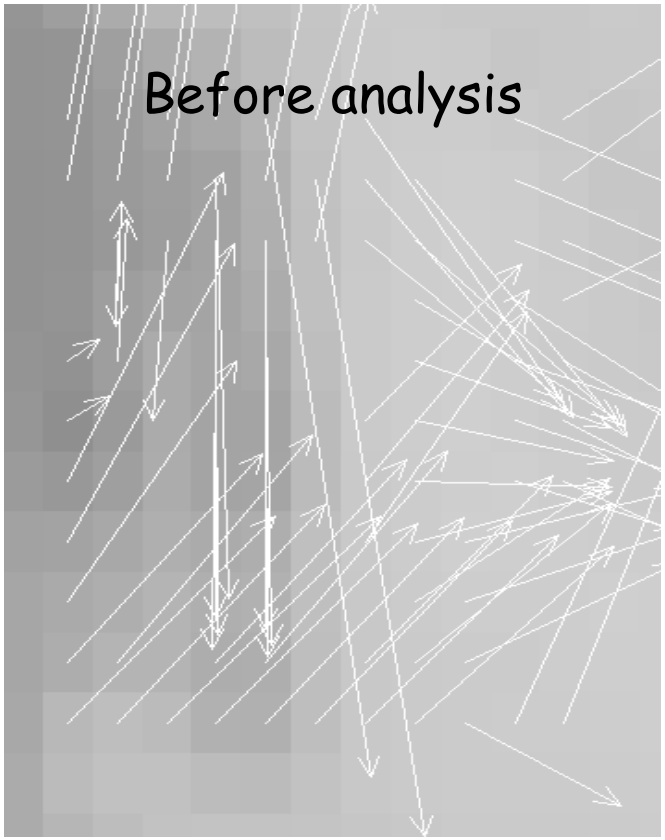
DBSCAN example:

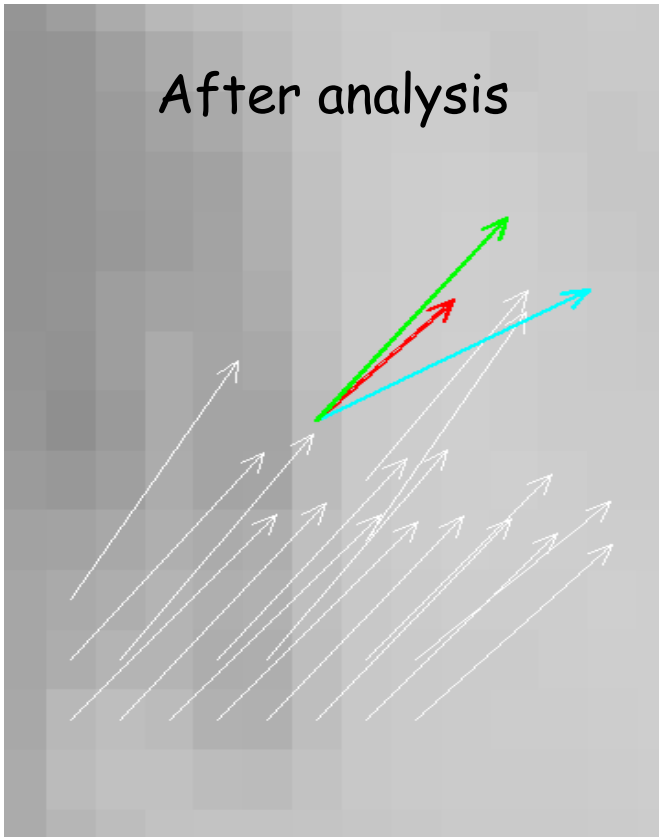


X – Average displacement of points in cluster

Nested Tracking Approach for Reducing Slow Speed Bias

Resulting vector field:





Motion of whole box

SPD: 25.0

Average of largest cluster

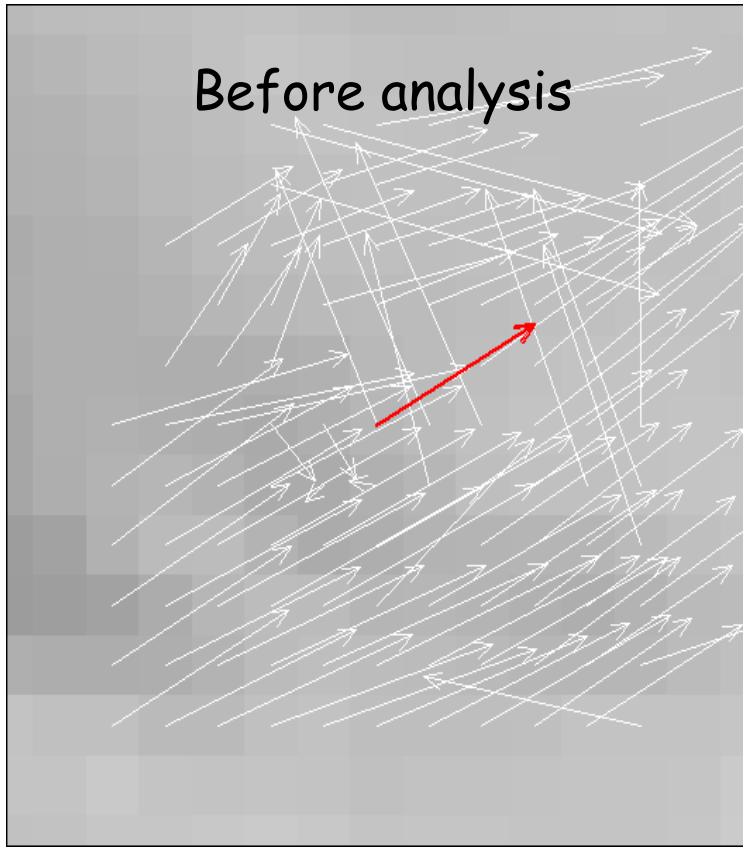
SPD: 39.8

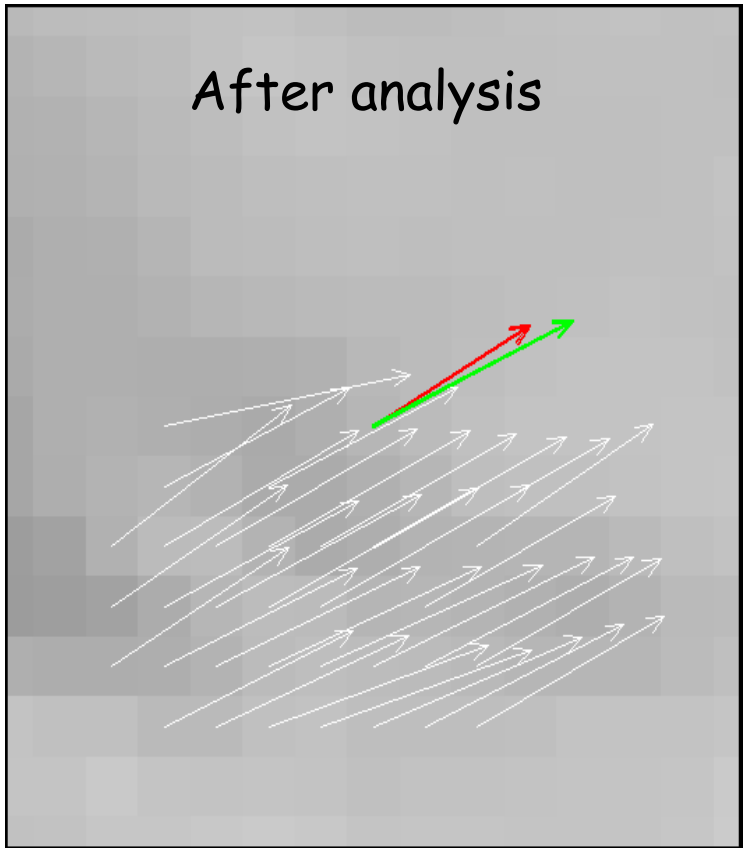
Forecast

SPD: 38.9

Nested Tracking Approach for Reducing Slow Speed Bias

Resulting vector field:





Motion of whole box

SPD: 22.3

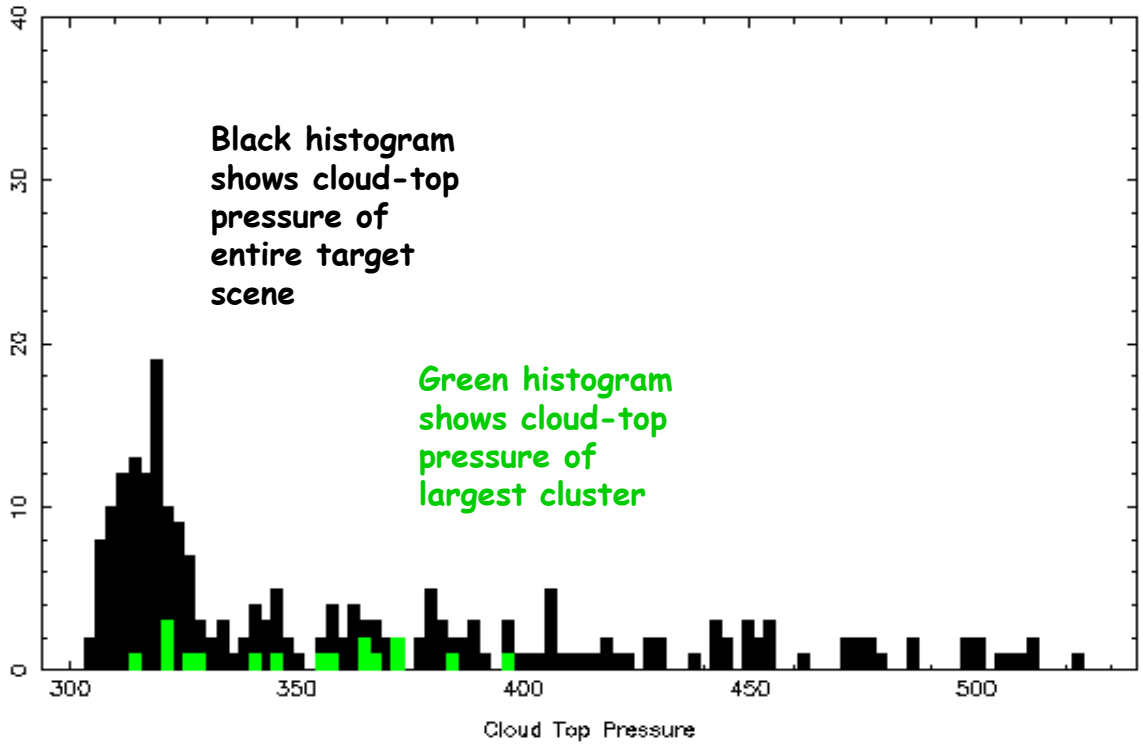
Average of largest cluster

SPD: 27.6

Nested Tracking Approach for Reducing Slow Speed Bias

Linking tracking to height assignment

- Use cloud height of pixels in largest cluster

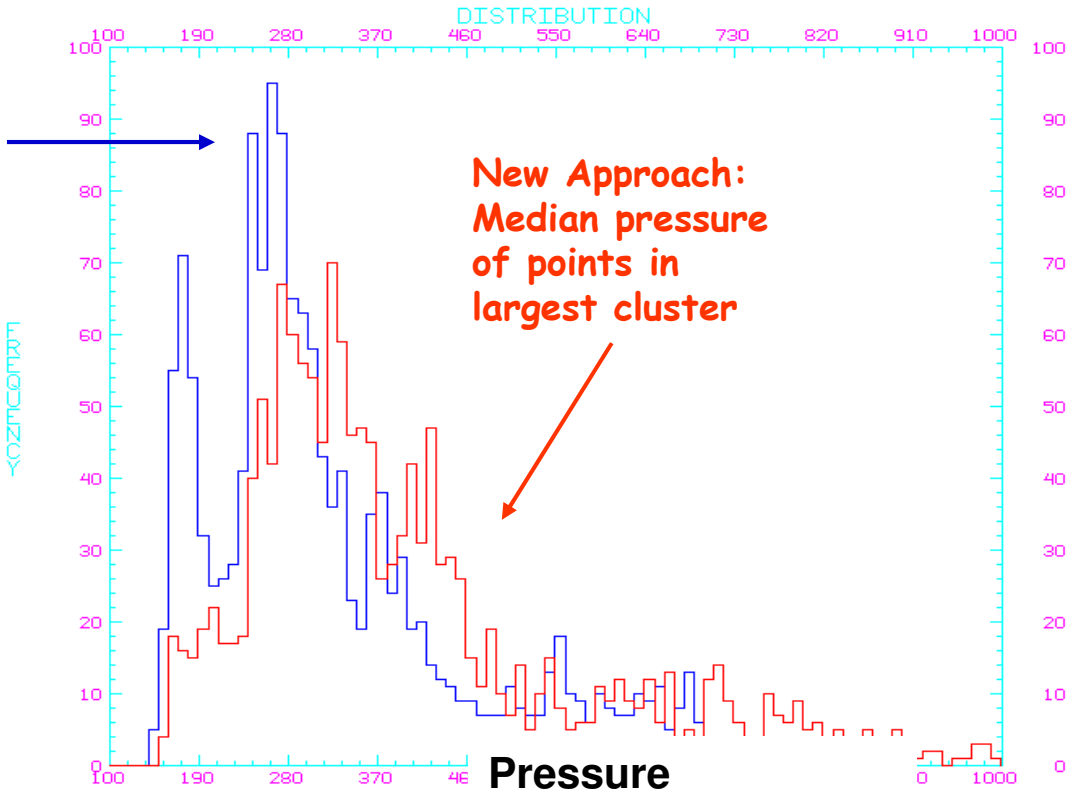


Nested Tracking Approach for Reducing Slow Speed Bias

Linking tracking to height assignment (cont.)

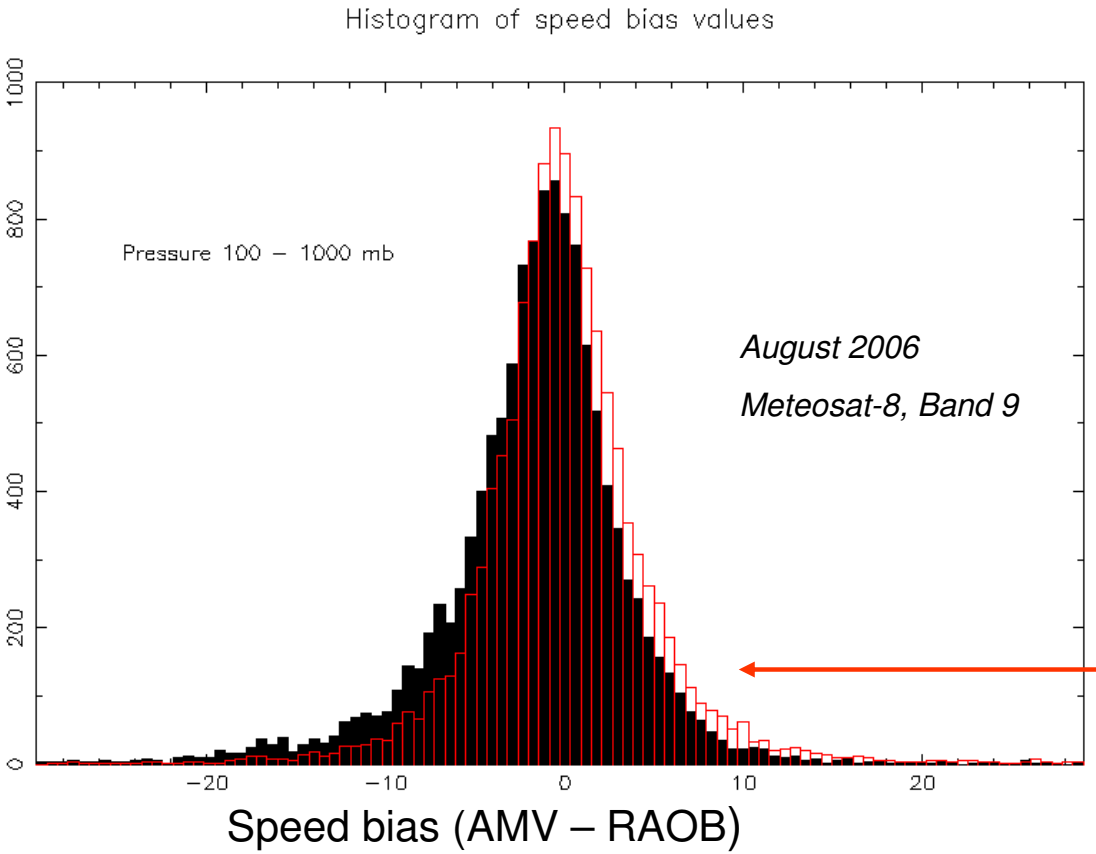
- Impact is to push heights lower in the atmosphere

Old Approach: Coldest 20% of pixels in 15x15 box



Results from Testing

Slow bias versus radiosonde is greatly reduced



Black histogram shows control

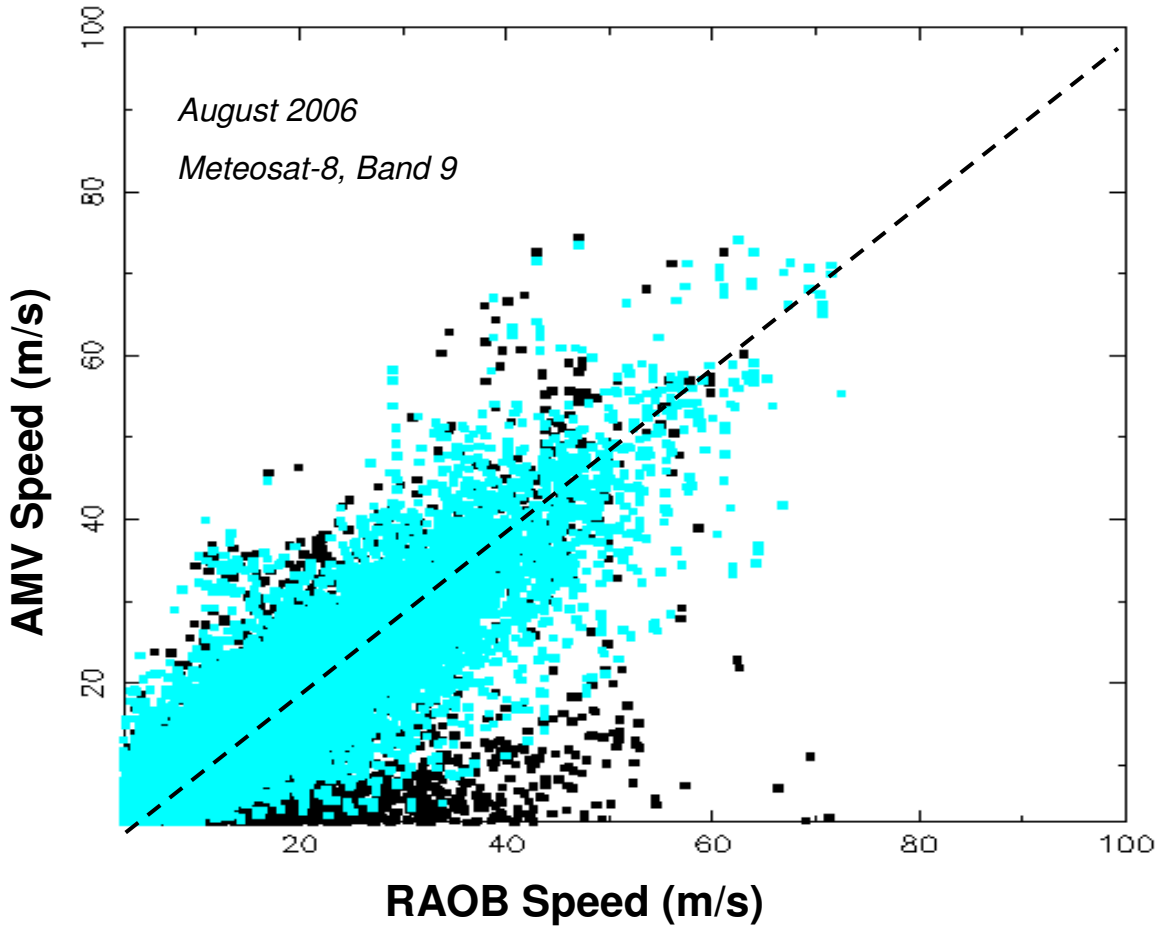
Red histogram shows test

Test distribution shifted right

- faster AMVs and/or lower heights

Results from Testing (cont.)

Test winds are better fit to radiosonde



Black – control

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

Light Blue –test

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

Results from Testing (cont.)

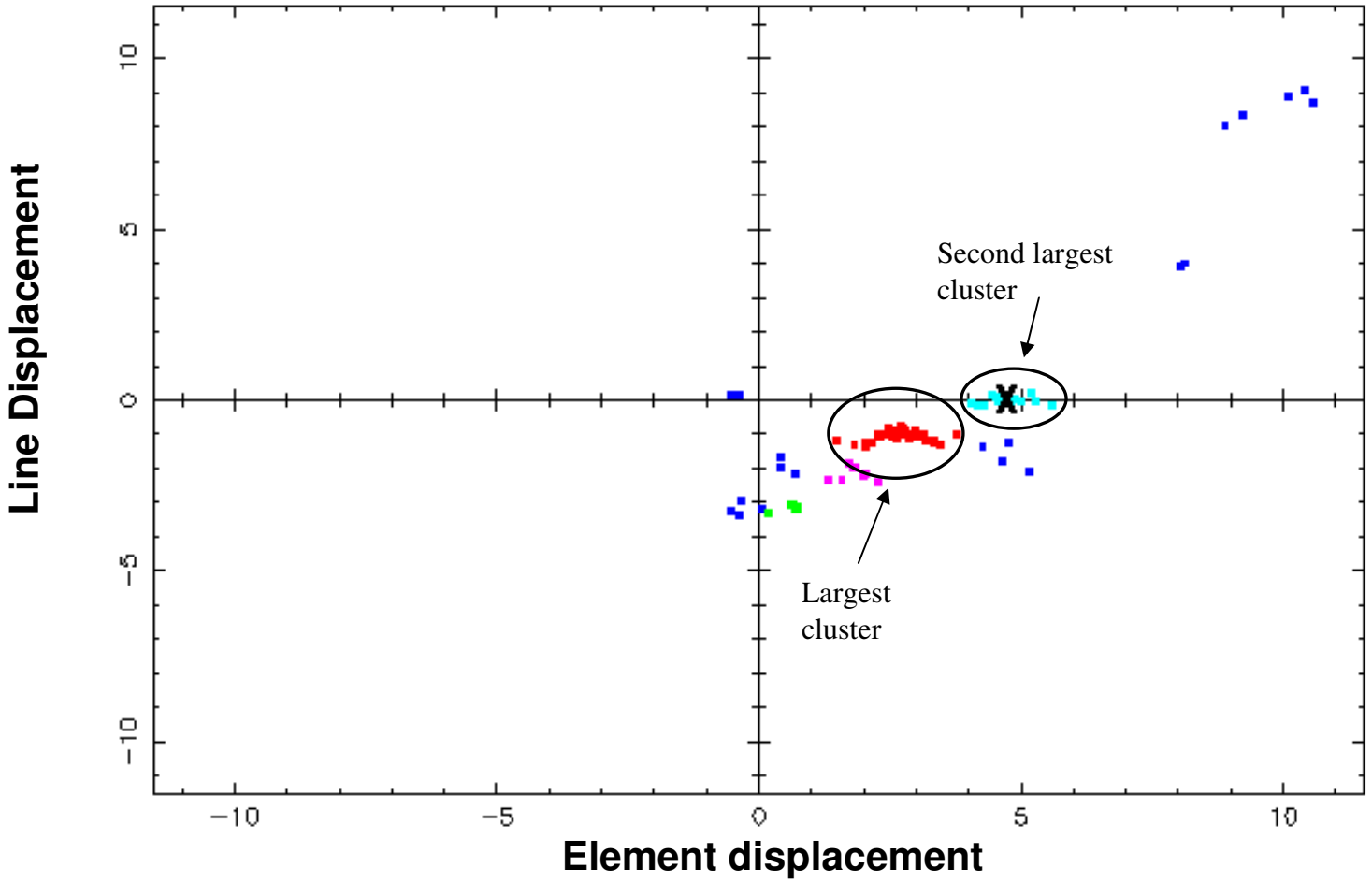
Statistical comparison:

	Control 15x15 box	Test (19x19 outer box) Largest cluster from 5x5 sample, new heights
RMSE	**7.53**	**6.63**
Avg Difference	**5.95**	**5.28**
Speed Bias	**-1.97**	**0.06**
Speed	**17.46**	**17.71**
Sample	**14548**	**14553**

Winds generated using Meteosat-8 10.8 μm imagery (15-minute loop interval) for the period Feb 1 - 28, 2008.

Results from Testing (cont.)

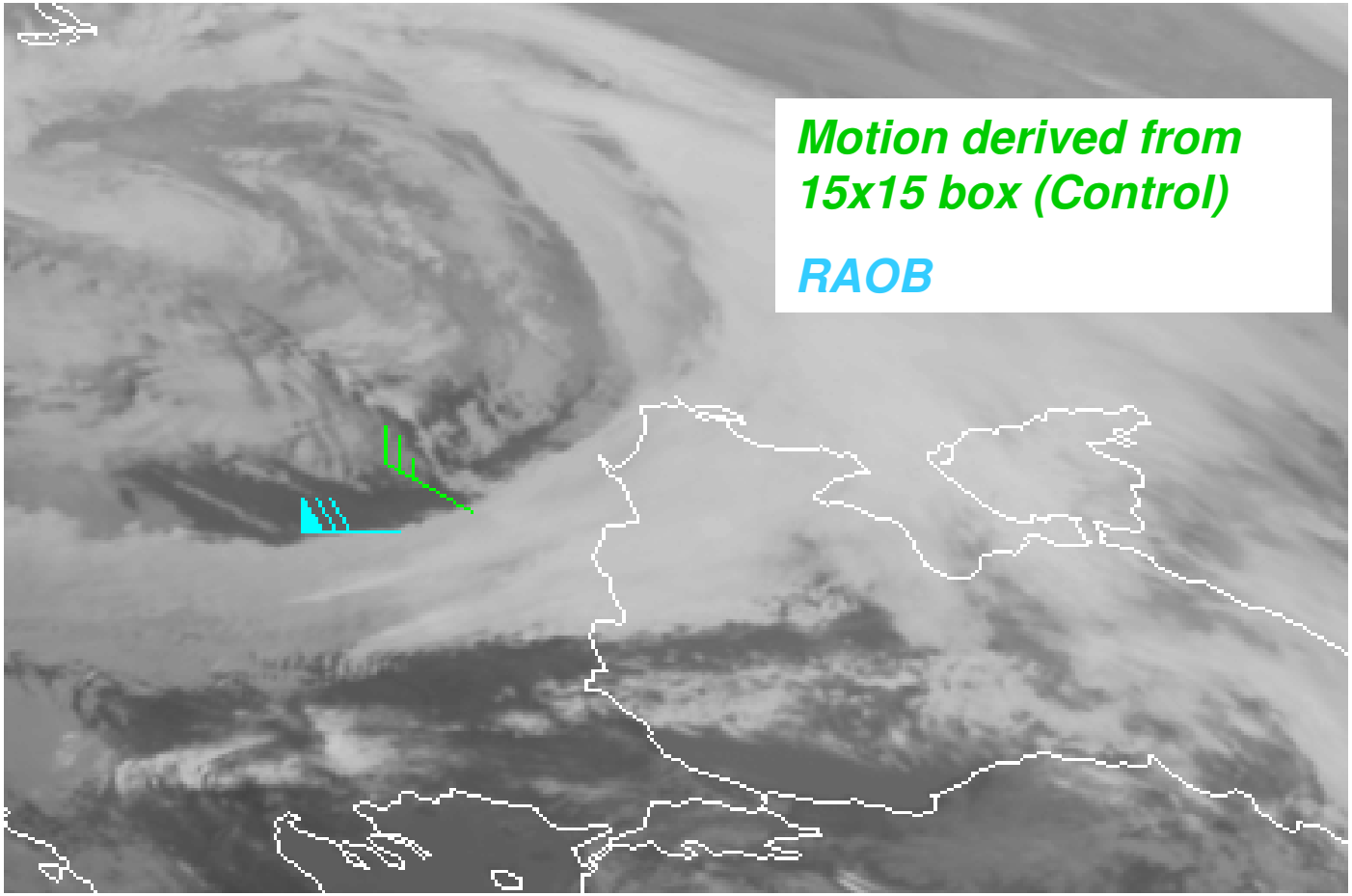
Potential Opportunity: Additional clusters may contain useful wind information (from different levels or scales) in the target scene



Red – motion of synoptic front

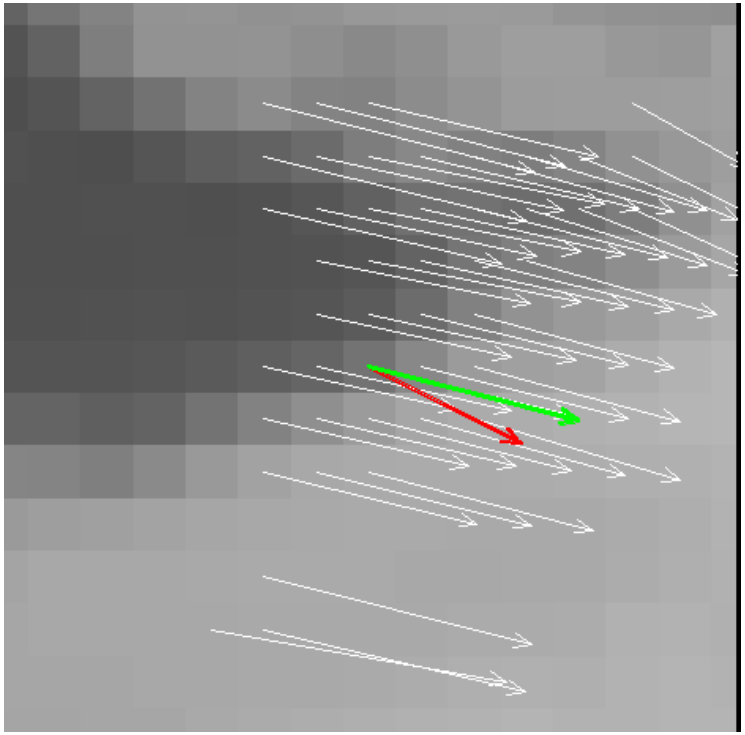
Light Blue – motion along front

Results from Testing (cont.)



Results from Testing (cont.)

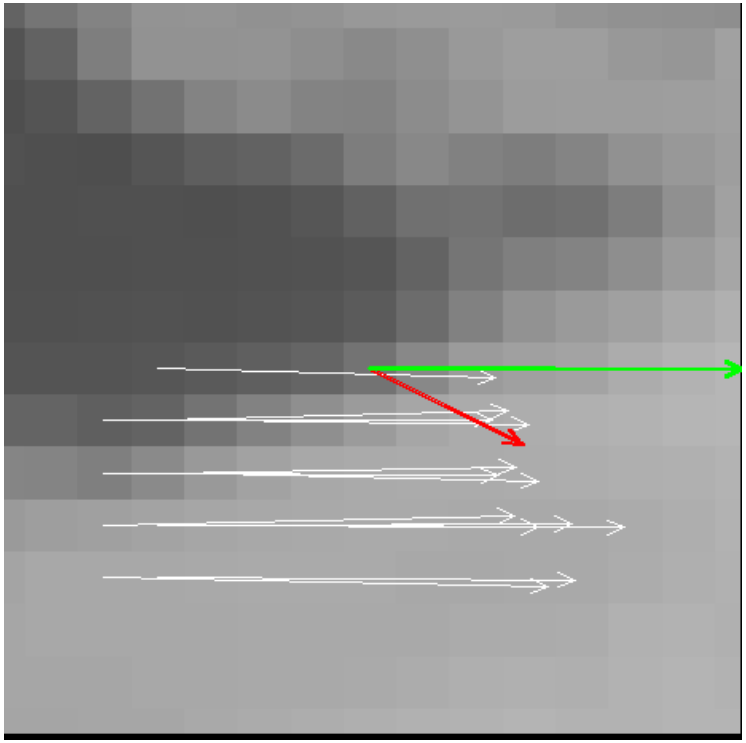
Additional Clusters:



Control – 15x15 (Speed: 12m/s)

Cluster 1

Speed: 15m/s



Cluster 2

Speed: 30m/s

Largest Cluster

Motion of front

Second Largest Cluster

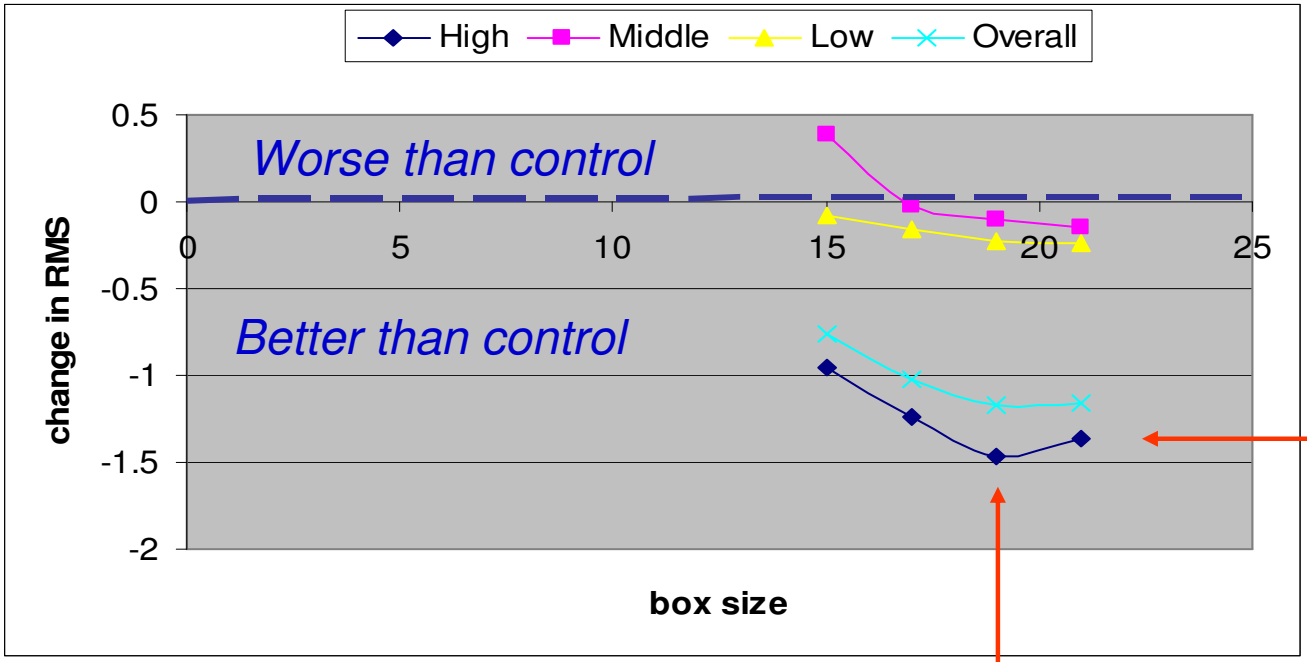
Better match to raob

Summary and Future Plans

- **Nested tracking approach effectively minimizes the slow speed bias**
  - Most speed "adjustments" are small, but some can exceed 10 m/s
  - Smaller bias a result of lower height and faster wind
- **Nested tracking approach also significantly reduces RMSE**
  - Greatest benefit seen at upper levels for IR winds
  - Smaller improvements for cloud-top WV
- **Identified opportunities with the nested tracking approach**
  - Additional clusters may contain useful wind information in the target scene
  - Use pixel level heights from cluster analysis to report layer information.
  - Clustering metrics may enable new quality control to be employed
    - Number of points in cluster
    - Number of clusters
    - mean distance of points in cluster
  - Extend cluster analysis to include height
- **Funded to extend new approach to current GOES winds processing**
- **Submitted a proposal to the Joint Center for Satellite Data Assimilation (JCSDA) to perform a NCEP GFS NWP forecast impact study using winds derived from new approach**

Backup Slides

Box size testing with new methods:

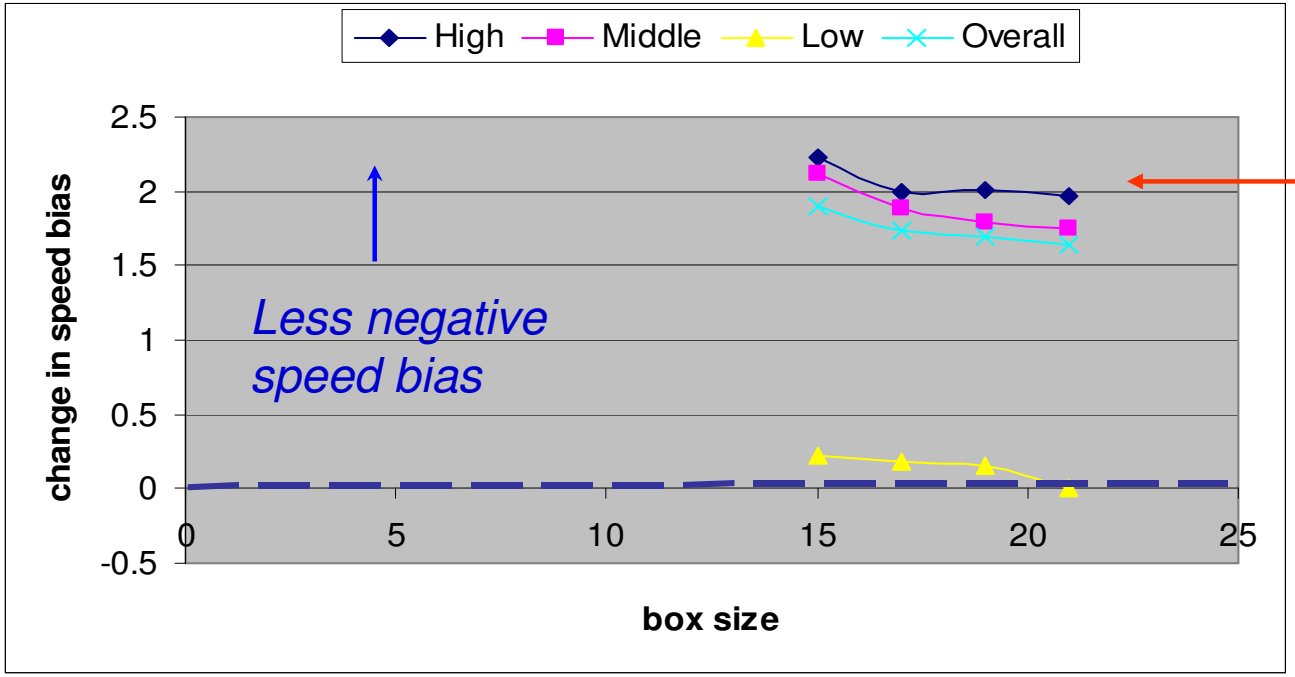


Largest impact at upper levels

19x19 box size is best relative to control

Backup Slides

Box size testing with new methods:



Slope levels off with larger box