Point-wise Wind Retrieval and Ambiguity Removal Improvements for the QuikSCAT Climatological Data Set

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Outline of Talk

- Overview of algorithm changes:
  - L1B to L2A algorithm changes
  - L2A to L2B algorithm changes
  - Post L2B algorithm changes
- Discuss validation studies performed to date.
- Overview of new NetCDF data product.

L1B to L2A Algorithm

- Reprocessing starts with the L1B data – the calibrated geo-located slice and egg σ0 observations.
- Our new 12.5 km product is based on slice composite σ0 observations, similarly to the previous 12.5 km product.
- The first step L1B to L2A algorithm is placing slice σ0 into wind vector cells (WVCs).
  - In the new dataset, we introduce an new and improved gridding algorithm which is used to place geo-located L1B slice σ0 data onto the L2A wind vector cell (WVC) grid.
- The 2nd stage is to composite all sequential slices from the same pulse that have been assigned to the same WVC into one L2A σ0 observation.

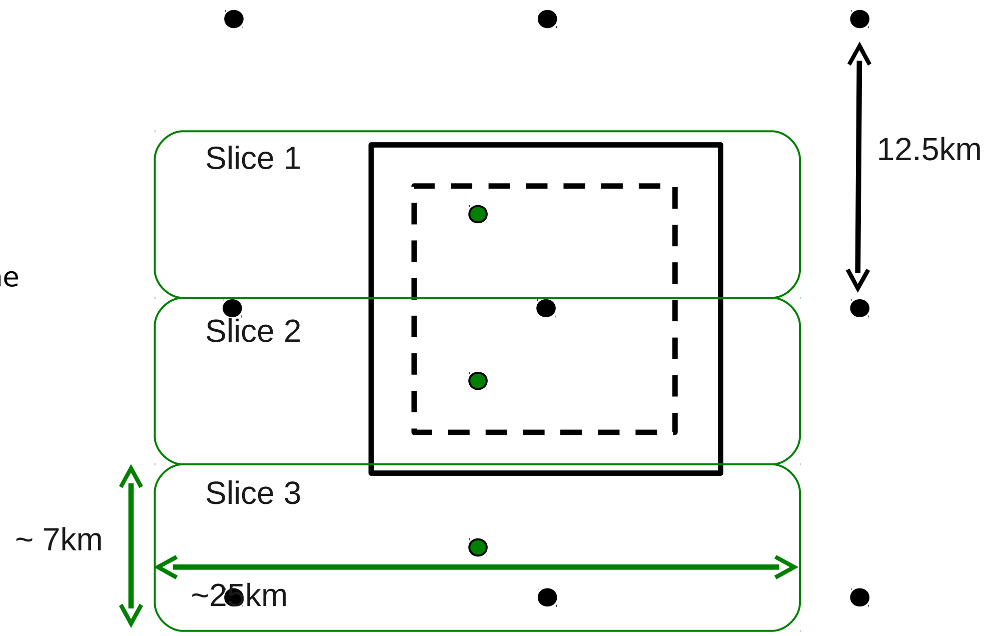
Overlap Algorithm

Centroid Algorithm (used in HDF 12.5km product):

- Place slice σ0 in WVC if centroid of slice lies within the WVC.
- The solid black square represents the middle WVC's extent and the black dots represent the centroid of the WVC.
- If slice σ0 centroid (green dots) lies within solid black square, place the slice σ0 observation in this WVC.
- In the case depicted, only slice 1 and 2 would be assigned to the center WVC.
- Each slice belongs to one and only one WVC.

Overlap Algorithm (to be used for climatological data set):

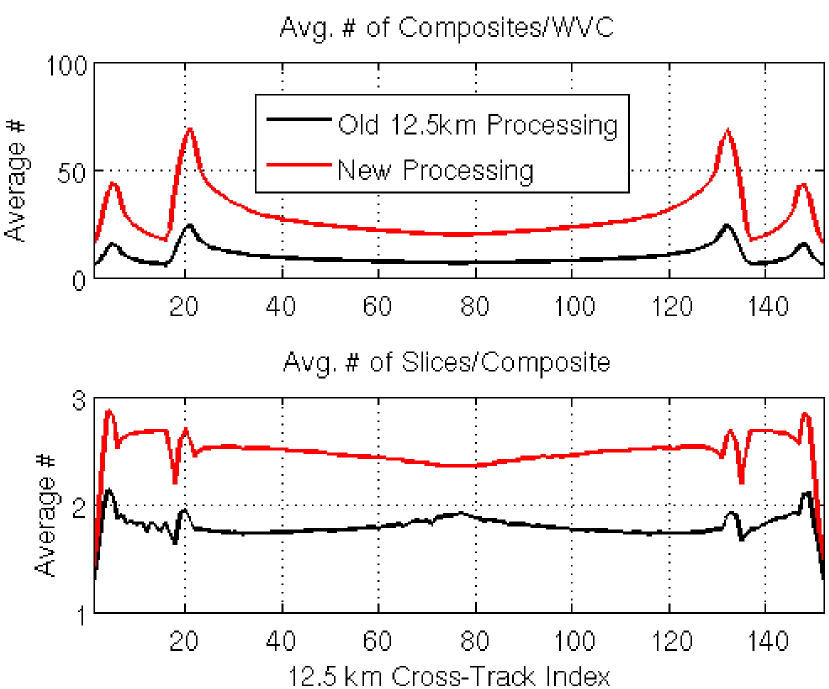
- Place slice σ0 in WVC if any portion of nominal slice (green outline) overlaps a configurable subset of the WVC.
- Dashed black line represents the overlap region.
- Slices 1, 2, and 3 would be assigned to the center WVC.
- *A given slice may be assigned to multiple WVCs*.

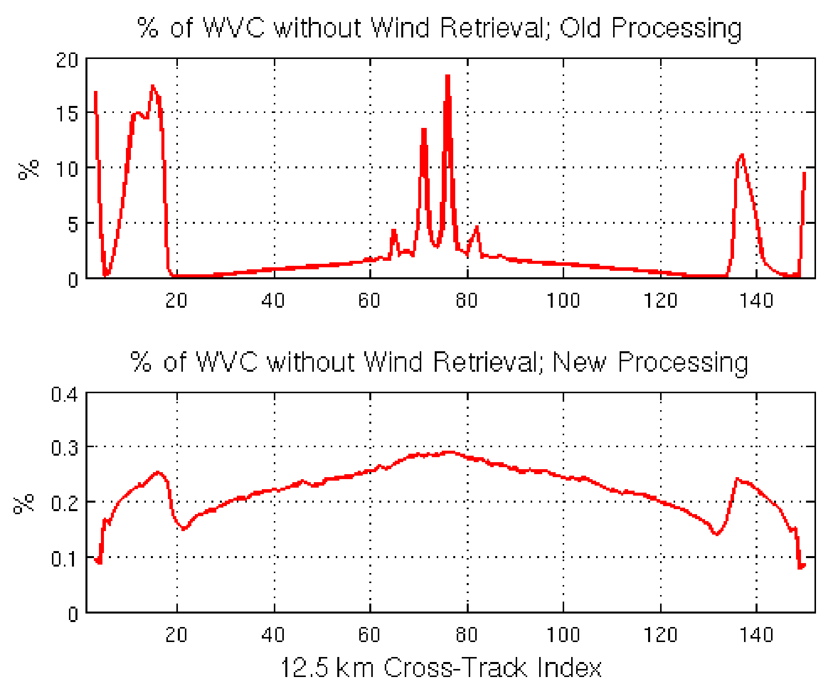


Toy Diagram of L2A WVC Grid and three sequential slice observations. Black dots are WVC centroids; Green dots are slice centroids. Solid Black square is extent of one WVC grid cell; Dashed black square is "overlap" region. Green outline represents the nominal slice boundary used in the overlap algorithm.

Effects of Overlap Algorithm

- Due to the overlap processing have many more composites / WVC than before
  - We also have more slices per composite.
  - Generally, this results in a vast reduction in # of WVCs without a wind retrieval in the nadir and boundary of dual-beam swath.
- Generally we have higher quality wind retrievals, except perhaps in the vicinity of rain where overlap processing can “smear” out rainy observations.





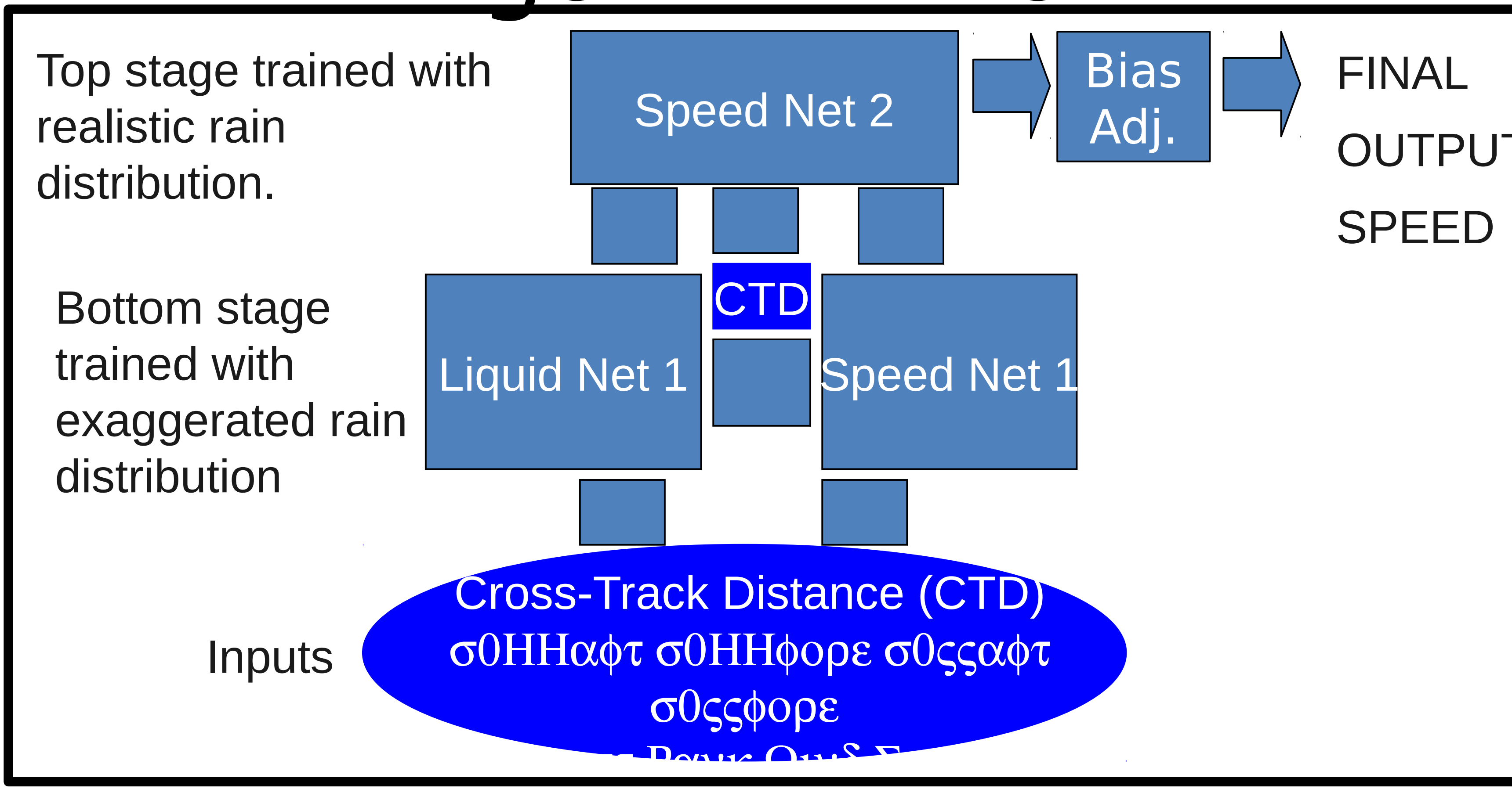
L2A to L2B Algorithm: New GMF

- RSS has developed a new model function for QuikSCAT (Ku2011)
- Based on 7 years of collocated rain-free QuikSCAT and WindSAT observations.
- We implemented this new GMF into our processing algorithms for the QuikSCAT climatological data set.
- Refer to RSS talk…

L2A to L2B Algorithm: Rain Flagging and Correction

- The rain flagging is unchanged from the previous 12.5 km QuikSCAT product. We report a rain flag valid bit and a rain detected bit in the new processing.
- We introduce a new rain-correction, which is based on an artificial neural-network.
  - The inputs are the 4 “flavors” of σ0, the cross-track distance as a proxy for instrument geometry, and the 1st rank wind speed.
  - We only perform this for the dual-beam swath; we do not have enough flavors of σ0 in the single-beam swath.
  - A rain impact quantity is estimated – this is output in the new data product as “rain_impact”.
  - Rain impact is intended to estimate the relative effect of rain on each wind vector cell.
- Rain Correction: If rain impact exceeds a threshold, we apply a rain contamination correction.
  - A speed bias is computed and applied which improves the speed performance in rain.
  - All ambiguities are given the same objective function value. Directional performance is slightly improved by setting the objective function values of all ambiguities equal before median filtering.

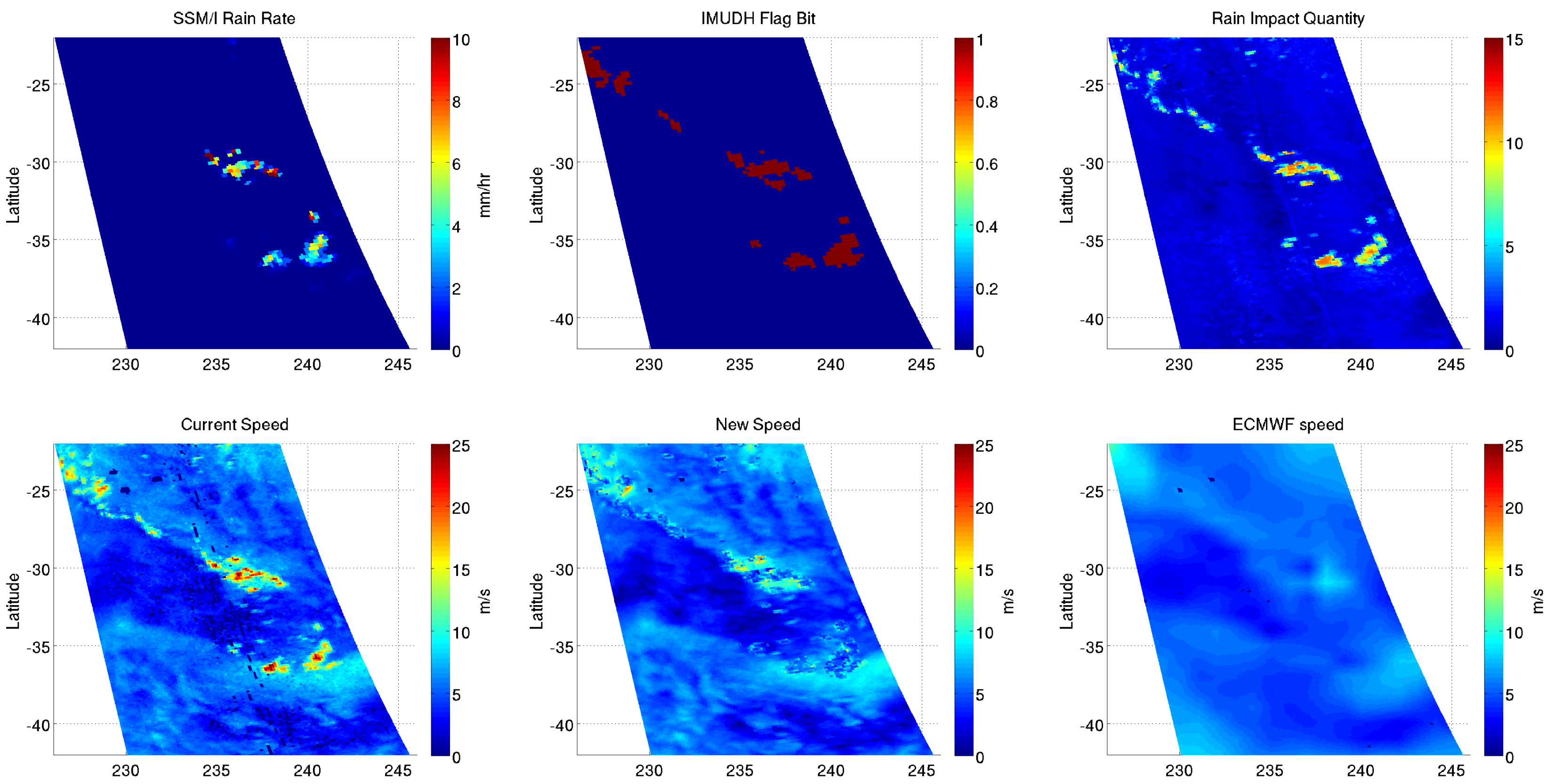
Rain Impact and Correction Algorithm Flow



Structure of neural network algorithm used to correct wind speeds for rain contamination.

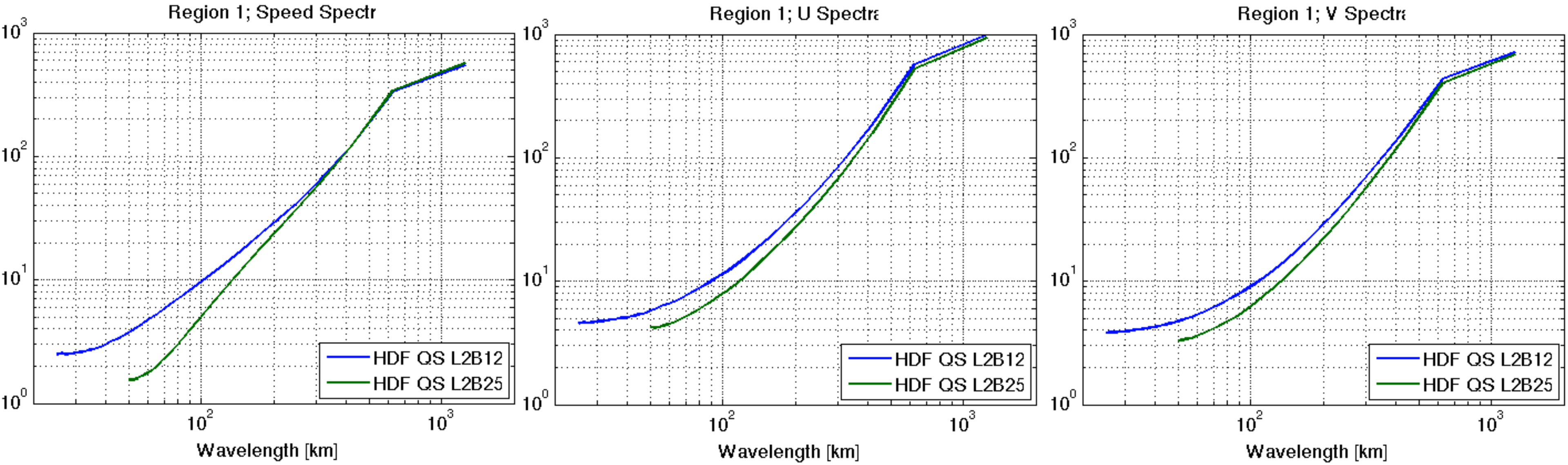
Example Wind Field

(observed by QuikSCAT and partially by SSMI on December 20, 2008 at 14:00 UTC.)



Post L2B Algorithm: Noise versus resolution Trade-off

- Previous L2B12 QuikSCAT product had rather large noise levels as compared to the 25 km product.
  - Particularly evident in the speed spectrum; notice the slope of the 12.5 km spectrum turns up at much larger wavelengths than the 25 km product.
  - U and V also showed the larger noise levels in the 12.5 km product.



Speed and Direction Filtering

- We propose to apply a post-L2B filtering of speed with a 5x5 Hamming filter.
  - Half-power of filter is ~ 37.5 km.
  - Filter the retrieved speed – ECMWF speed.
- We propose to apply a 3x3 median filter to the direction field
  - Filter ei(ϕL2B-ϕECMWF) (i.e the phasor).
- These filters give improved spectra for the speed and direction, but the main effect is on the wind and stress derivatives.
  - They were far too noisy before.
  - With proposed filtering, they are much better behaved.

Wind Divergence – Old processing and New

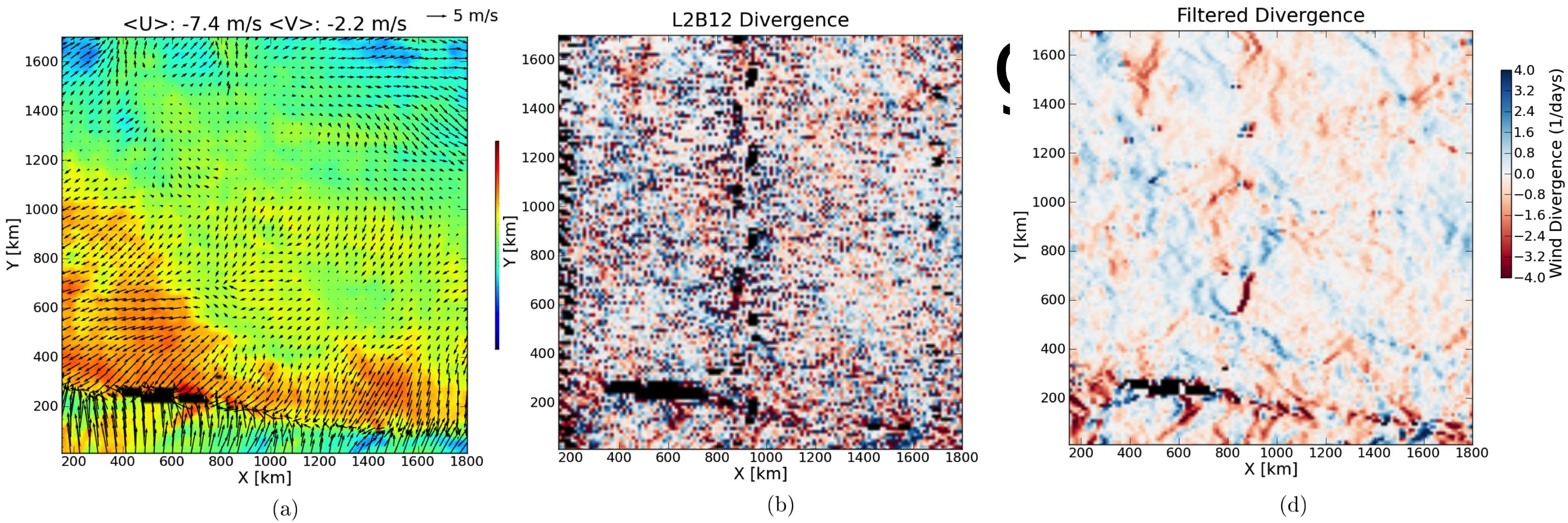


Figure 14: (a) Tropical wind field including a front and rainfall (black masked out region). The color represents the wind speed and the arrows are the residual wind vectors after subtracting a constant wind vector (-7.4,-2.2) m/s. The divergence for the same scene is calculated using L2B12 12.5 km data (b), L2B 25 km data (c), and using the filtered winds recommended here (d).

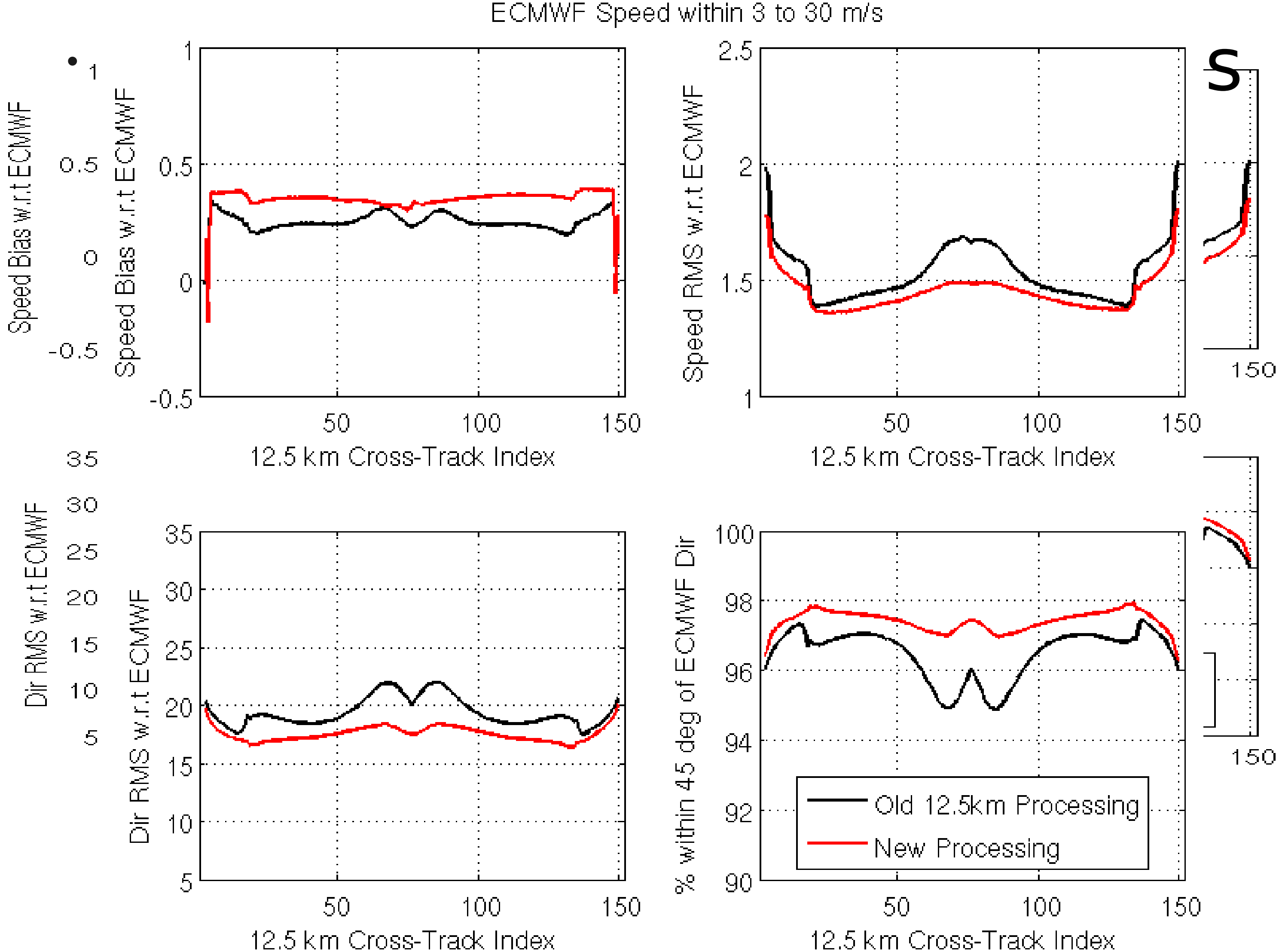
Figures and caption from: Improved Wind Directions, Divergence, Vorticity and their Spectra for the QuikSCAT Scatterometer. Ernesto Rodriguez and Alexandra Chau, 2011 (pre-print)

Validation Performed to Date

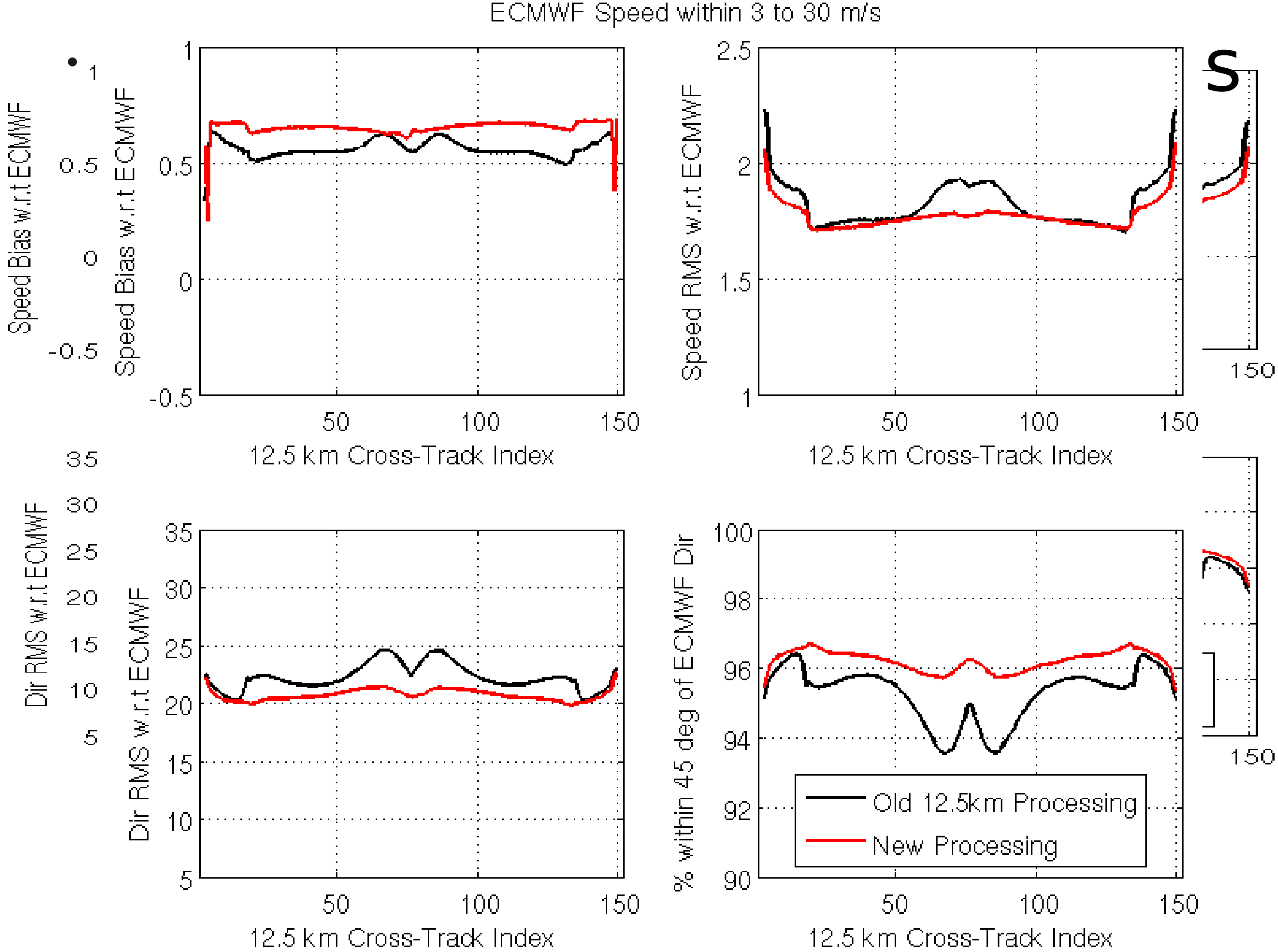
- We have processed all of year 2000 and all of year 2008 with our new algorithms and model function.
- Comparisons to ECMWF
  - Histograms of speed, direction, u, and v component differences
  - Speed bias, RMS speed, RMS direction differences.
- Comparisons to Buoy observations
  - Speed bias, RMS speed, and RMS direction differences.
- Spectral Comparisons of new product to HDF 12.5 km product and ECMWF

Rain Free Validations

Rain-Free Comparisons to ECMWF



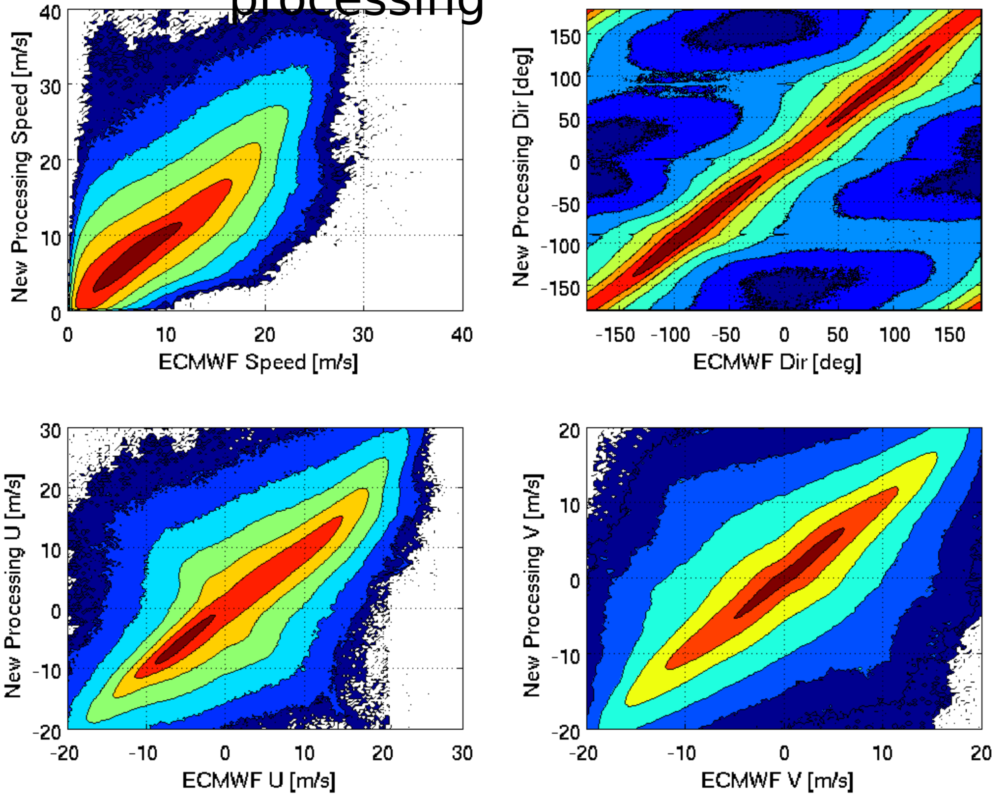
Rain-Free Comparisons to ECMWF



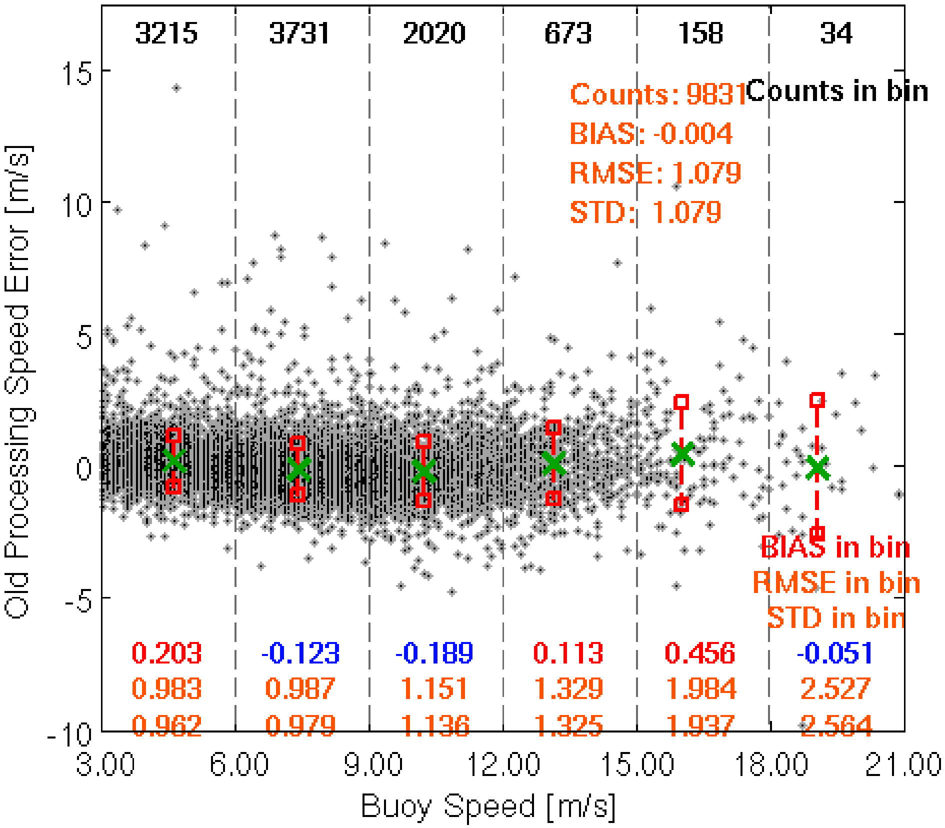
2D Histograms – All 2008 Rain Free

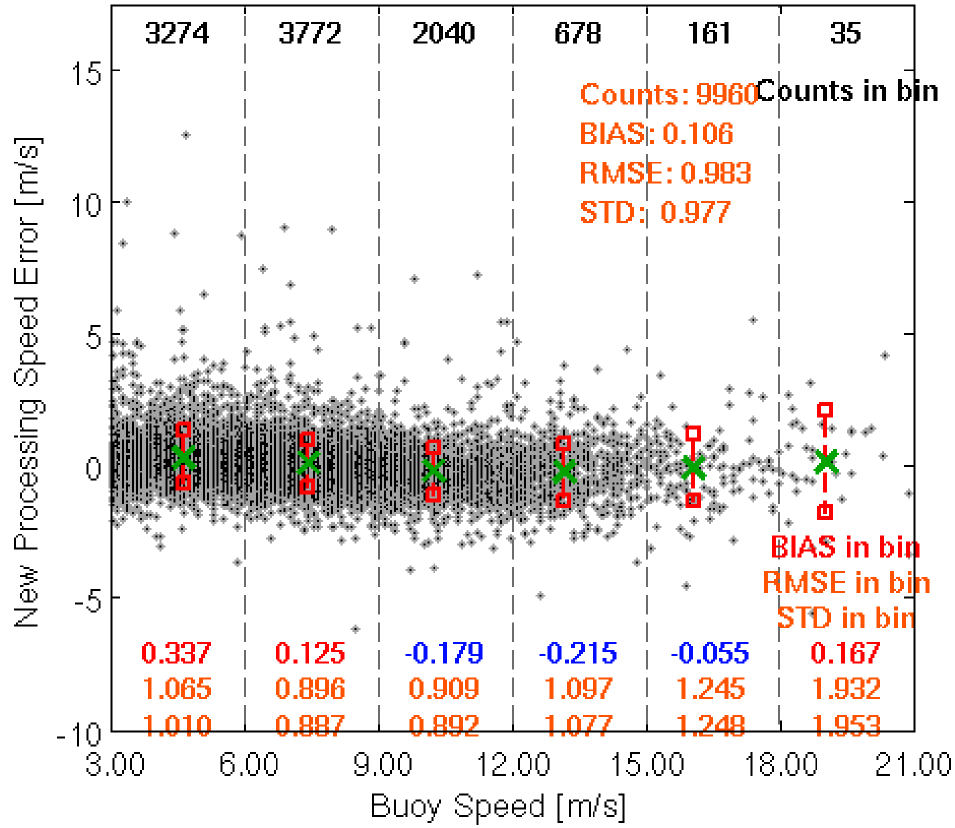
Old 12.5 km processing

New 12.5 km processing

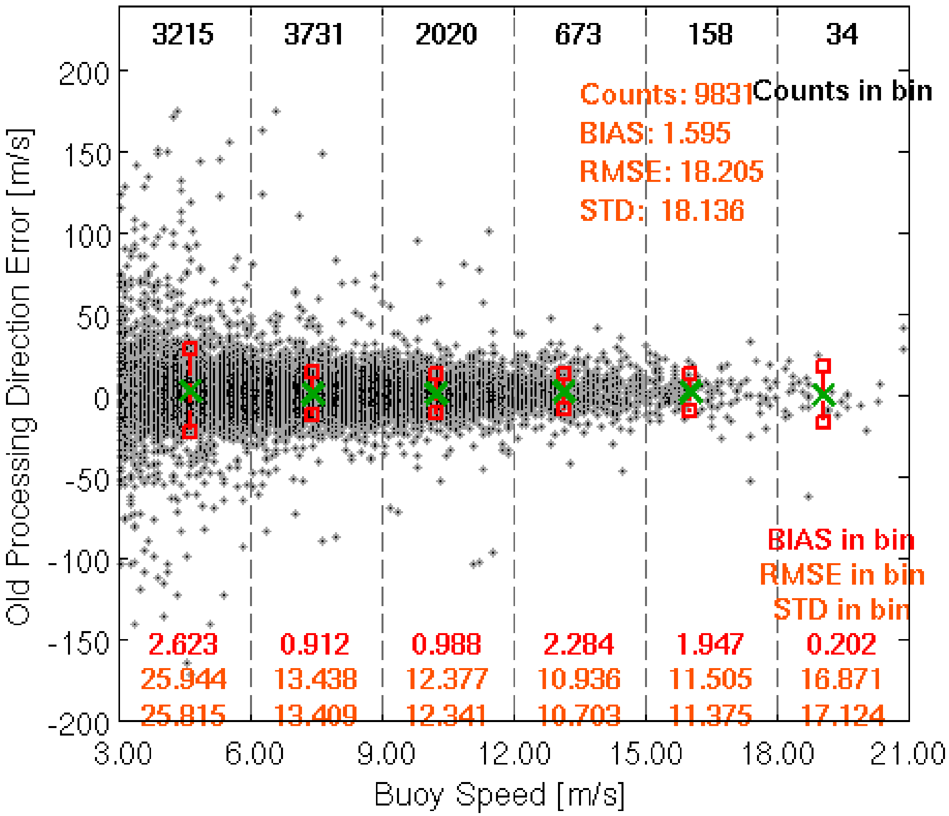


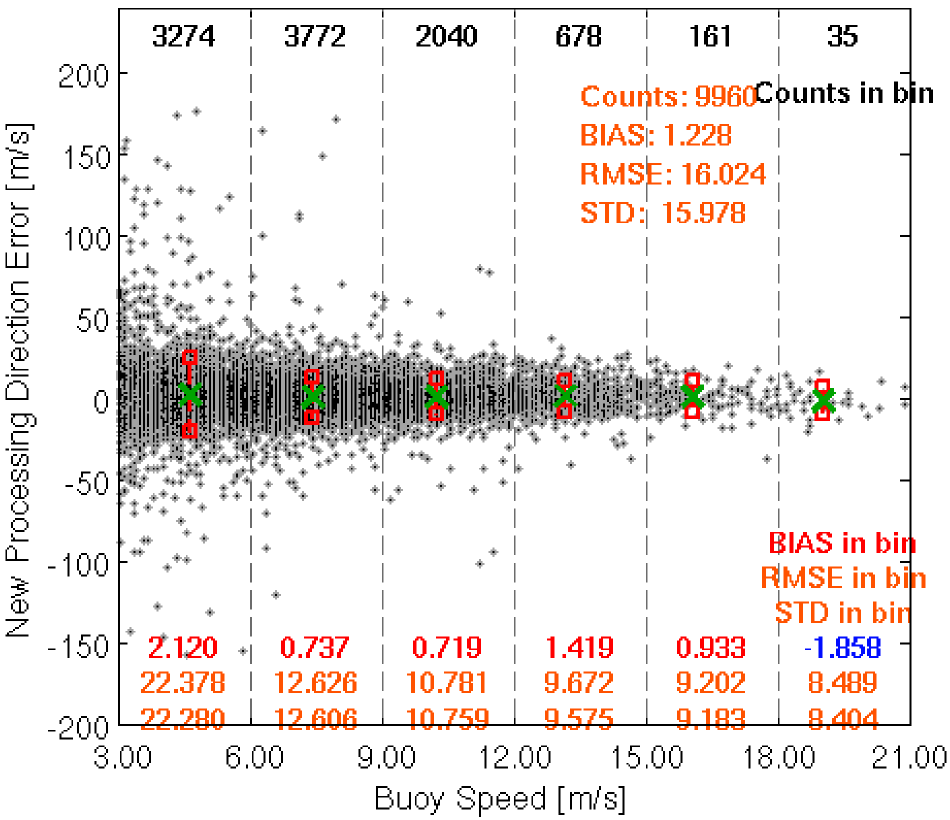
2008 Speed Errors Compared to Buoys





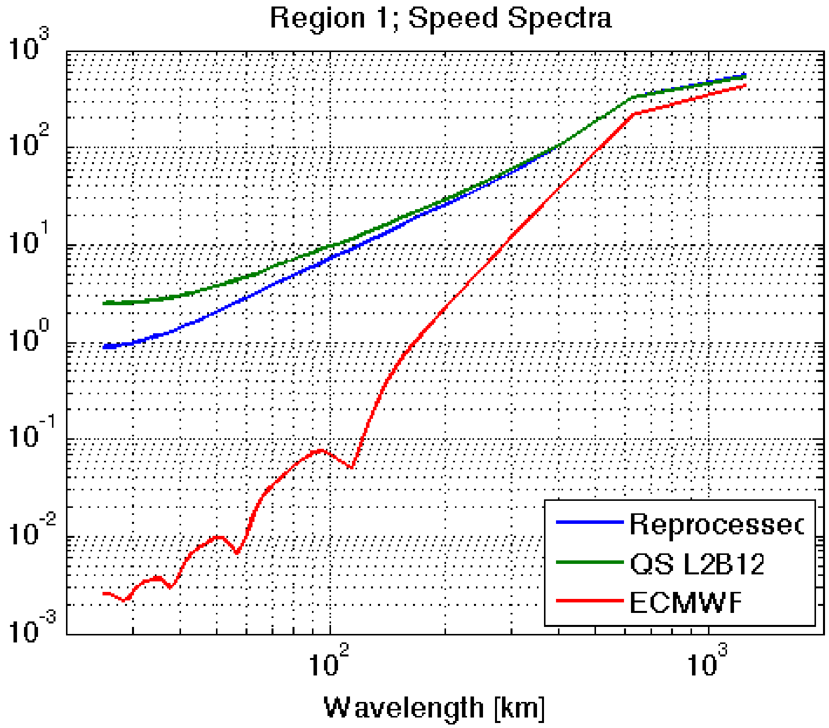
2008 Direction Errors Compared to Buoys Rain Free (Only NDBC

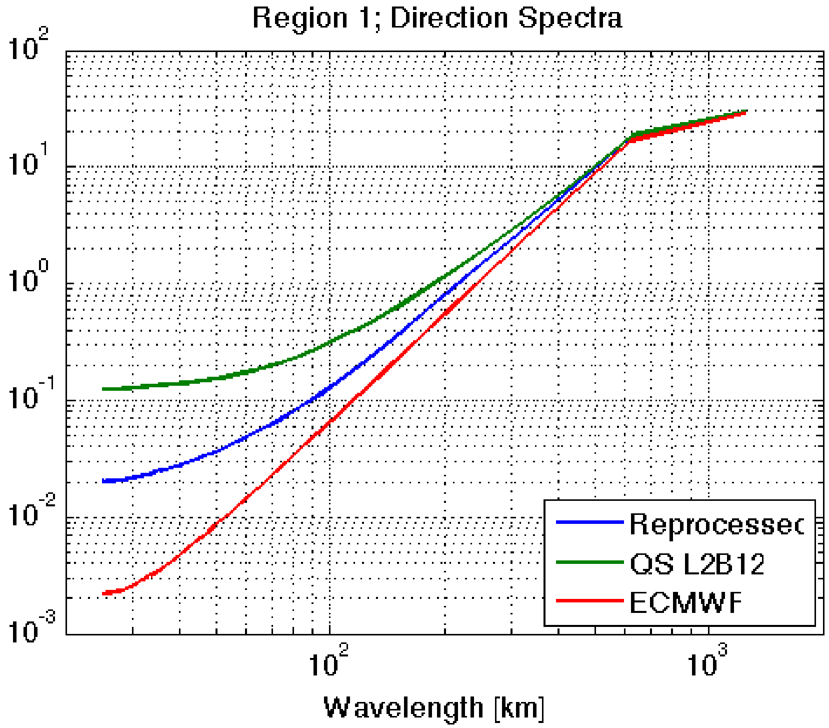




Spectra; All 2008; Region 1

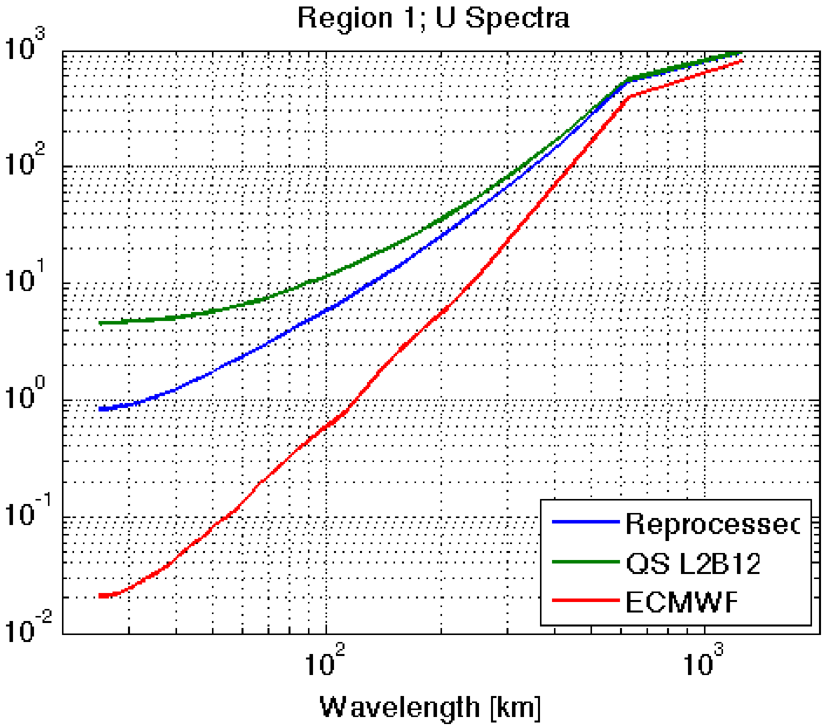
- Significantly less noise than previous 12.5 km product
- Most pronounced in direction spectra (spectra of phasor)

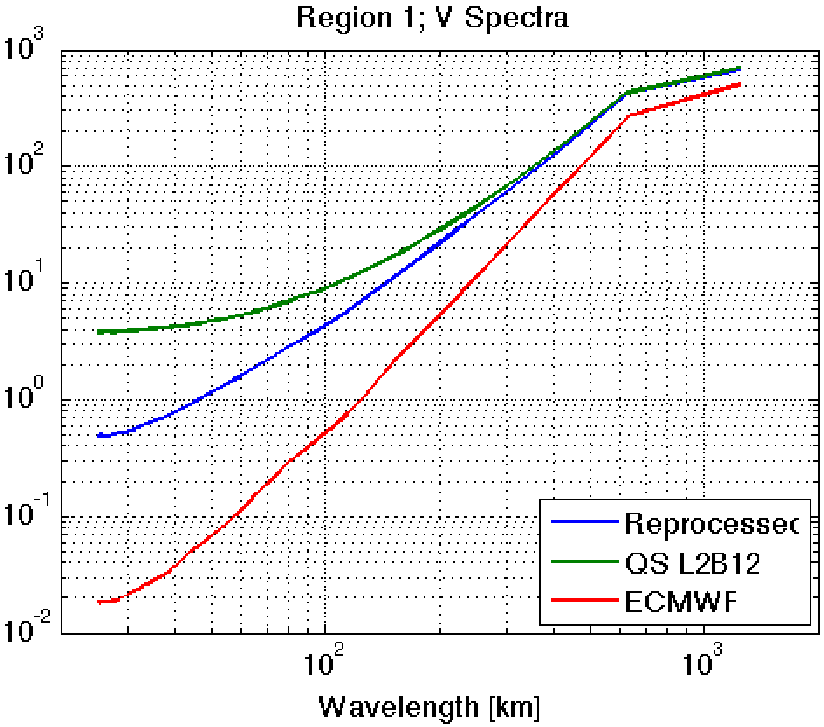




Spectra; All 2008; Region 1

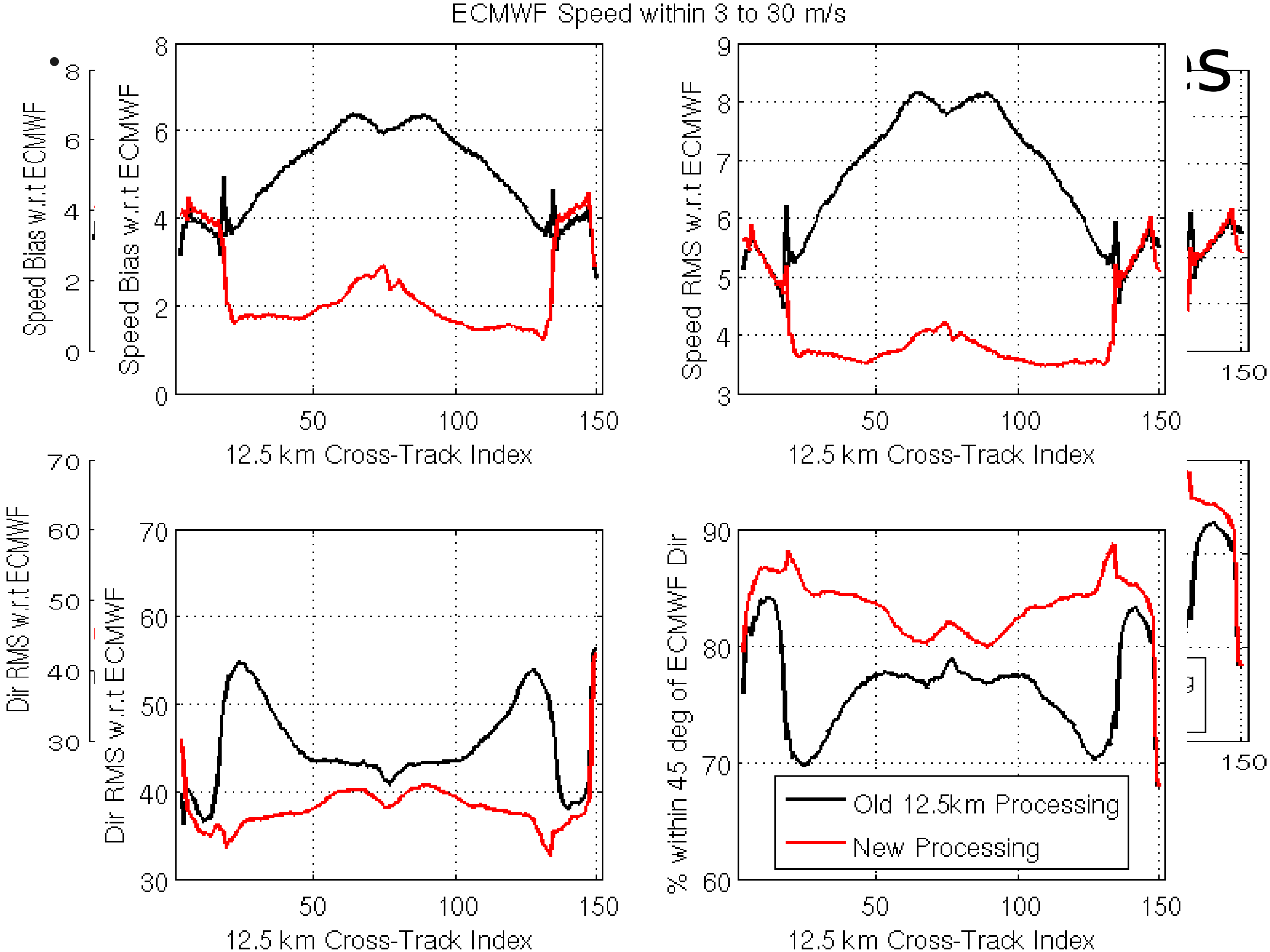
- Similar observations for the spectra of the U and V components.
  - We have not included the post-L2B smoothing (yet) in these results!





Rain Flagged Validations

Rain-Flagged Comparisons to ECMWF All 2008

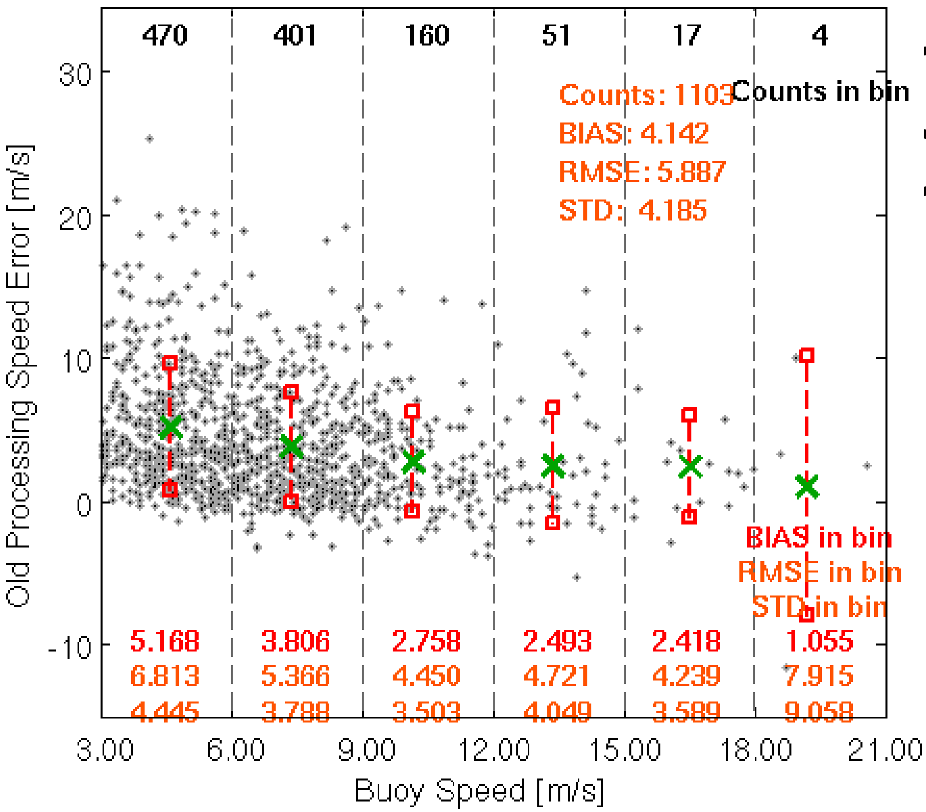


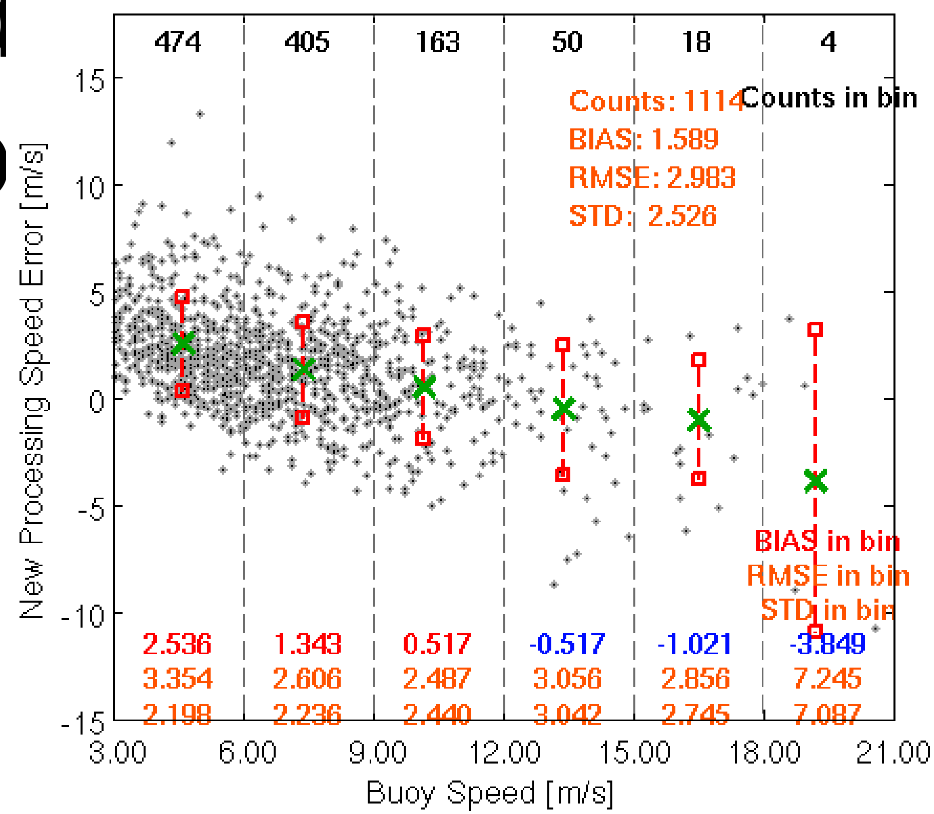
2D Histograms – All 2008 Rain Flagged

Old 12.5 km processing

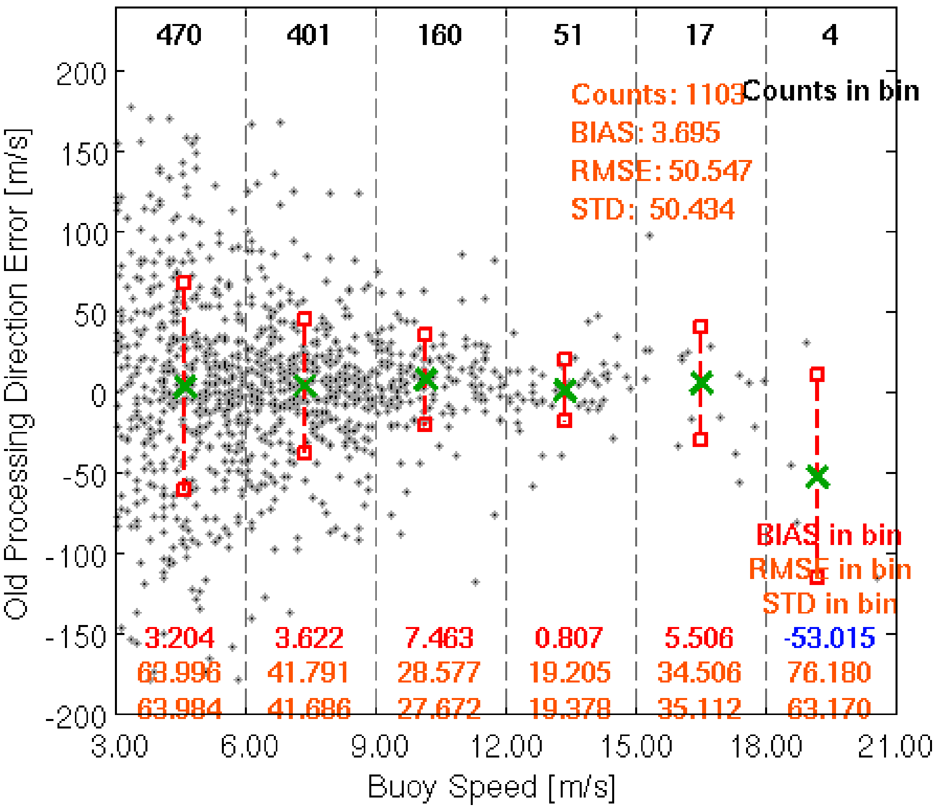
New 12.5 km processing

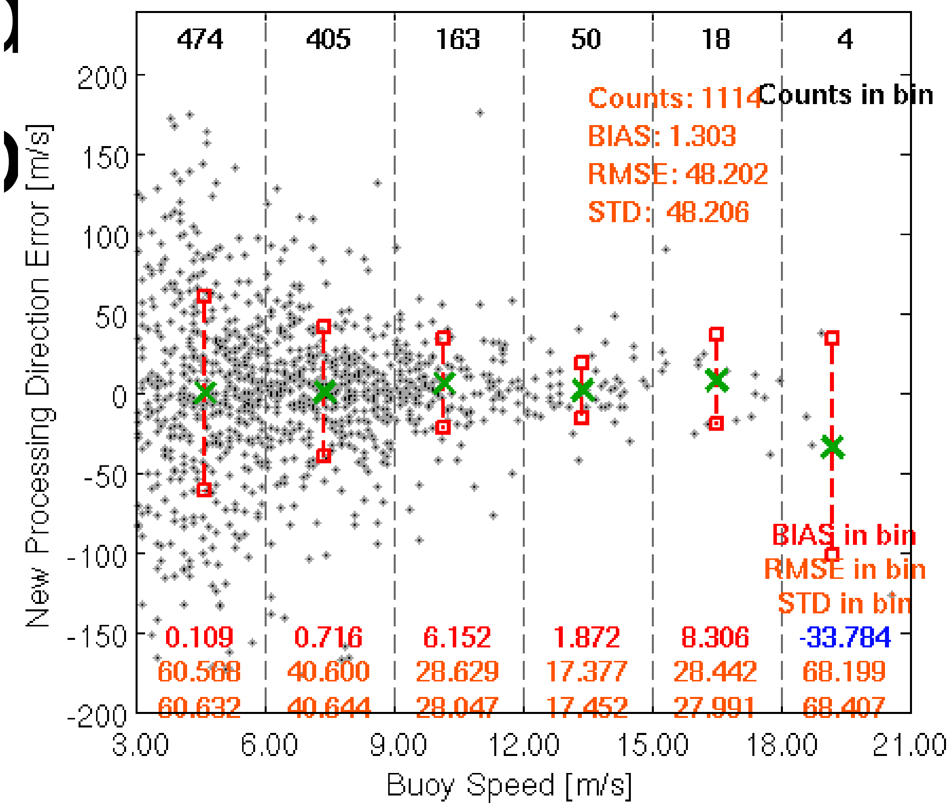
2008 Speed Errors Compared to Buoys Rain Flagged (All Trusted





2008 Direction Errors Compared to Buoys





Overview of NetCDF Product(s)

Two "Flavors" of data:

Unfiltered Product

- Contains native resolution output from L2B processing
- Contains the following datasets:
  - Lat, Lon
  - Cross-track wind speed bias
  - Rain corrected Wind speed, direction
  - Rain impact
  - Atmospheric speed bias
  - Quality Flags
  - Nudge wind speed, direction
  - Retrieved wind speed (without rain correction)
  - Number of ambiguities
- Intended users:
  - Scatterometer experts

Filtered Product

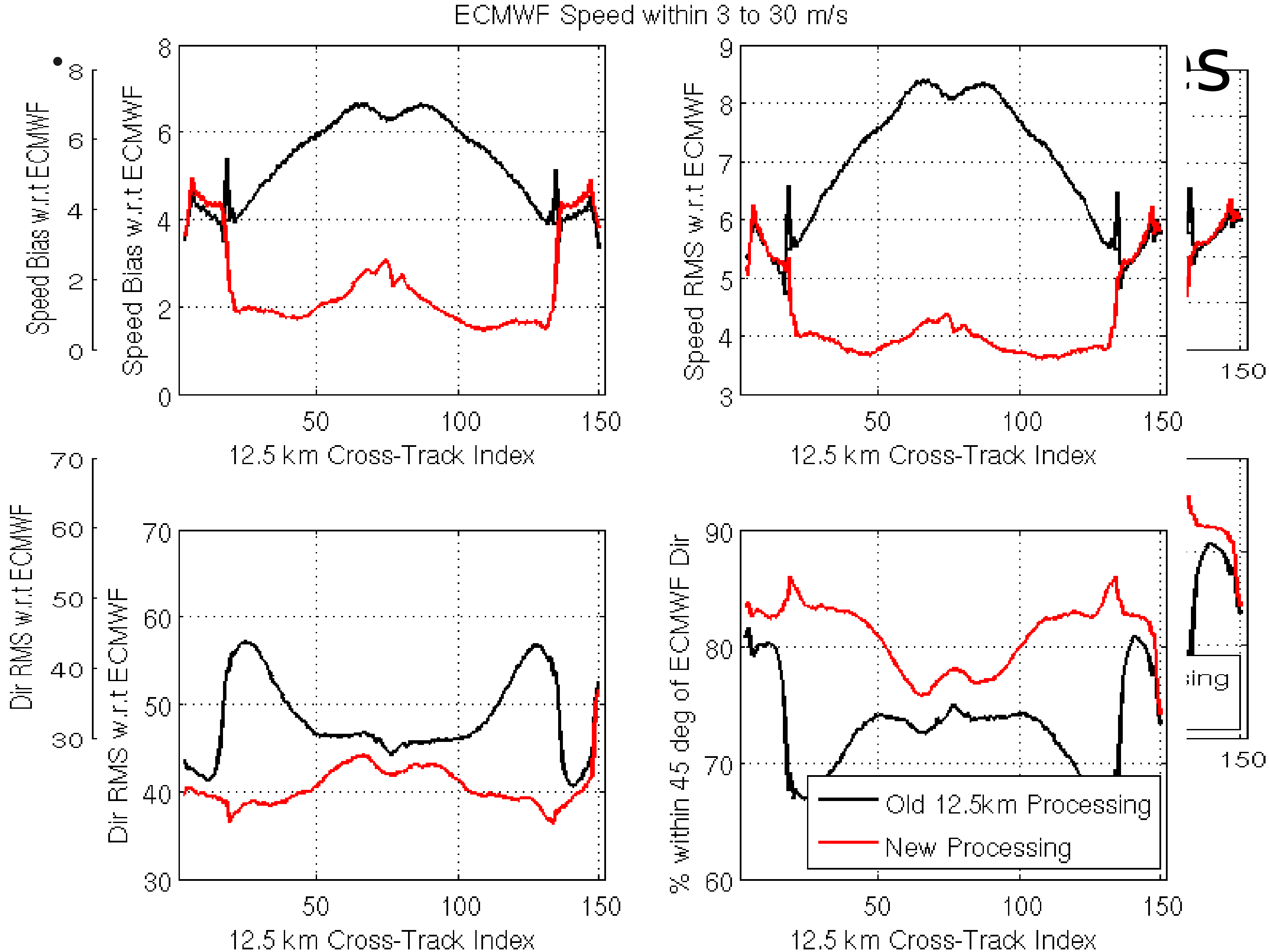
- Optimal trade-off of noise and resolution
- Contains the following datasets:
  - Lat, Lon
  - Wind speed, direction
  - Wind divergence, curl
  - Stress
  - Stress divergence, curl
  - Quality Flags
  - ECMWF speed, direction
- Intended users:
  - Oceanographers
  - Climatology
  - Users who want best dataset

Summary

- Major changes to new processing:
  - Improved gridding algorithm that results in less “holes” in 12.5km product.
  - Incorporation of new model function.
  - Rain correction algorithm that significantly improves performance of rain-flagged data.
  - Optimal noise versus resolution trade-off.
- New NetCDF data products containing wind and stress derivatives (divergence and curl).

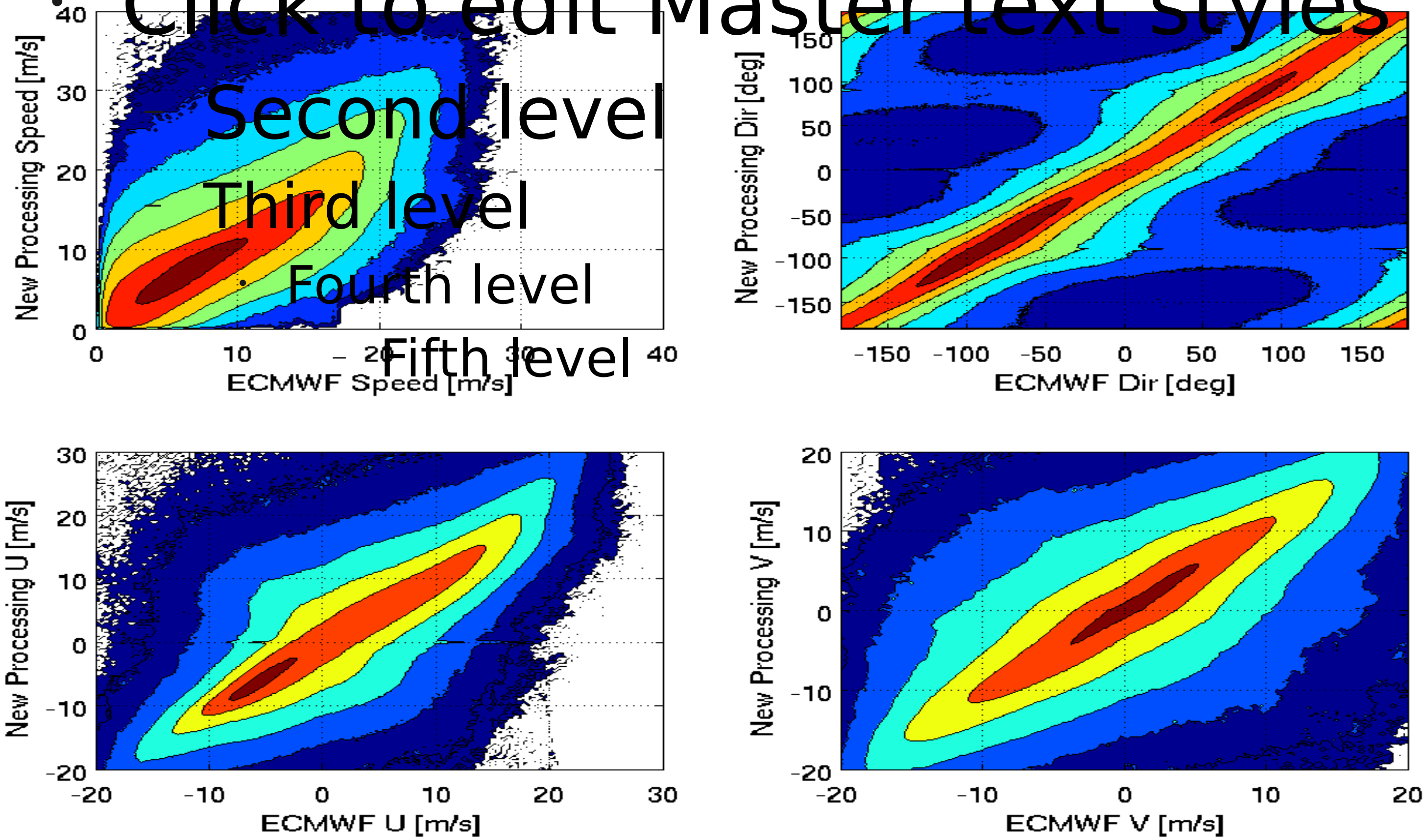
Backup / Extra Slides

Rain-Flagged Comparisons to ECMWF All 2000



2D Histograms Compared to ECMWF

- Click to edit Master text styles
  - Second level
    - Third level
      - Fourth level
        - Fifth level



2008 Old Processing
Rain Free (all trusted buoys)

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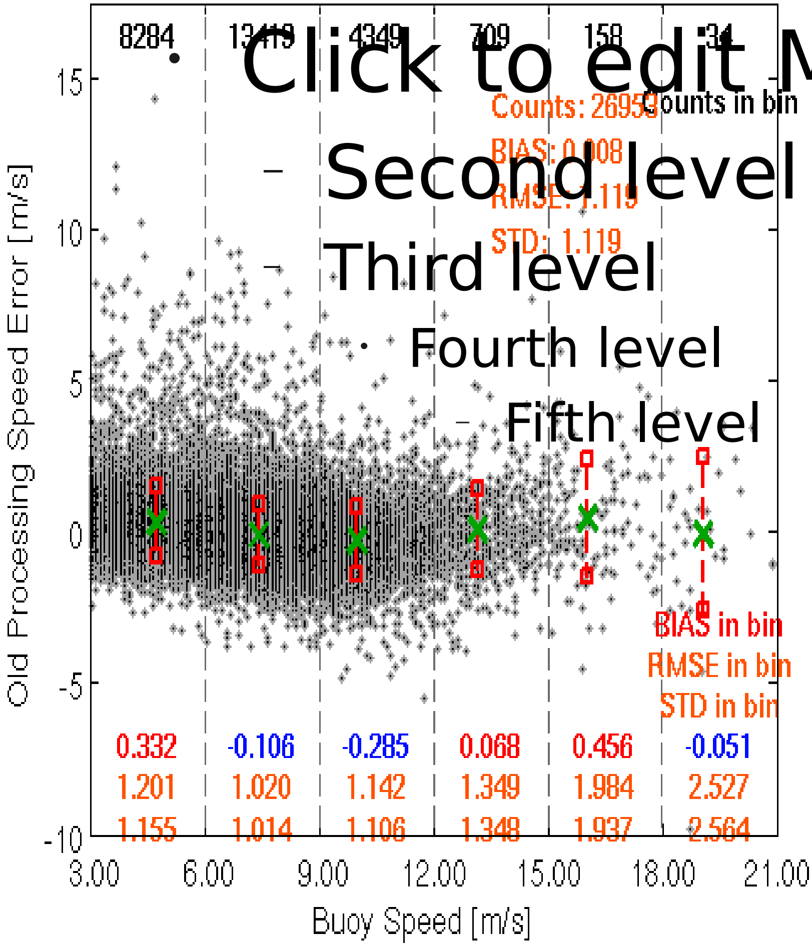
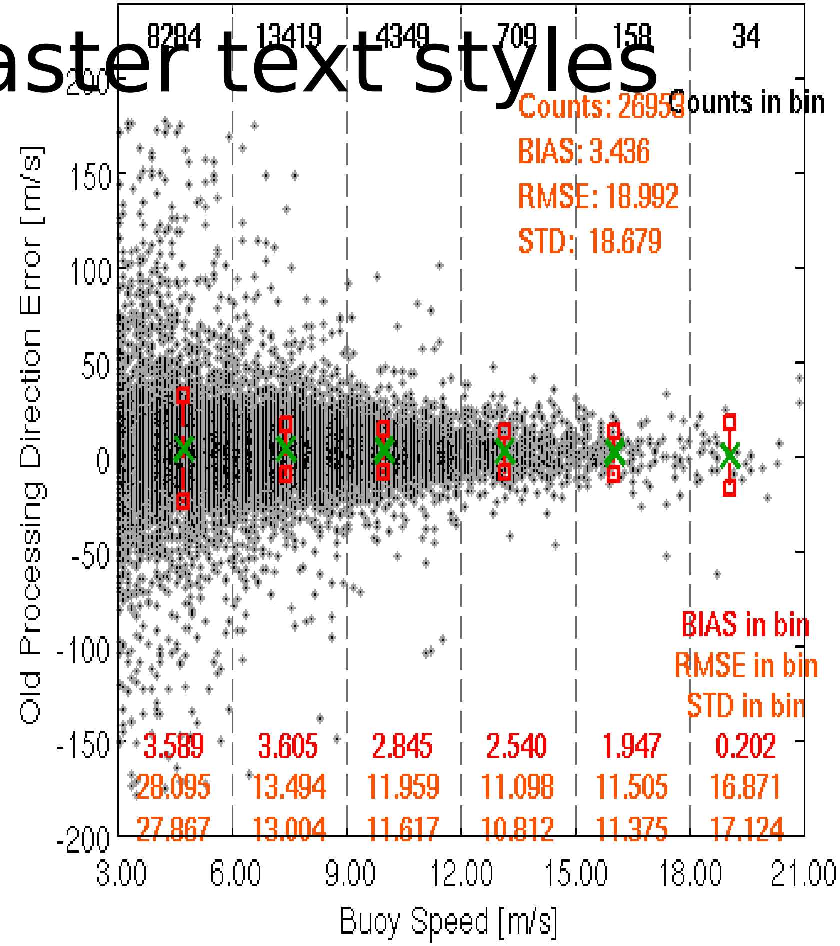
    - Third level
      - Fourth level
        - Fifth level





2008 New Processing Rain Free (all trusted buoys)

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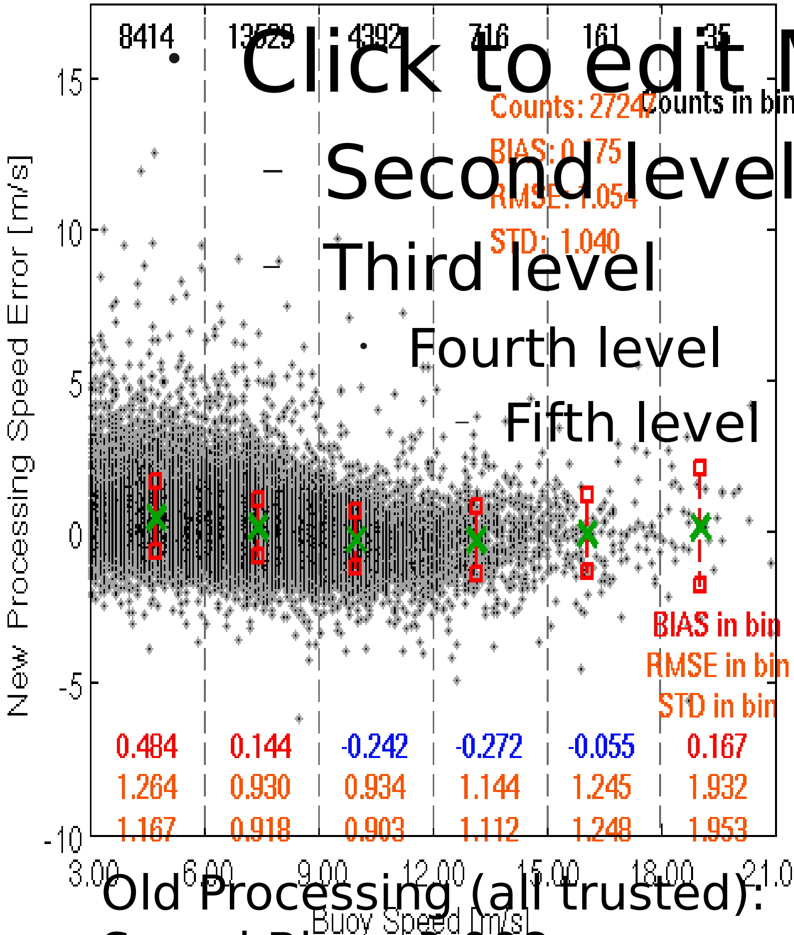
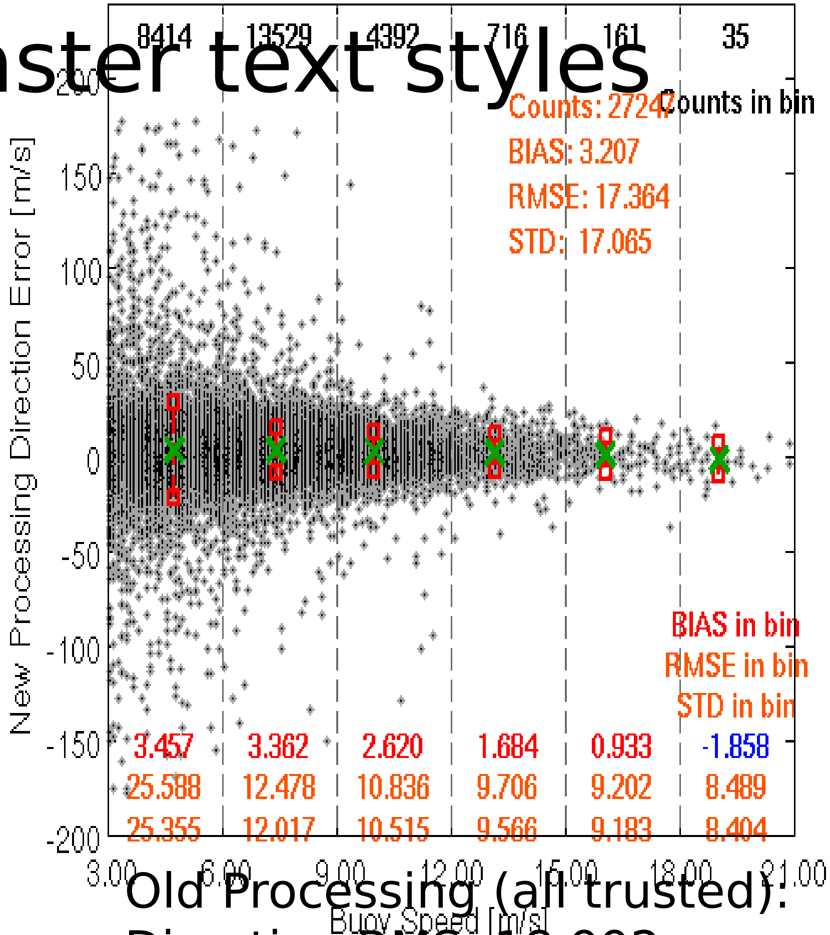


Old Processing (all trusted):
Speed Bias: 0.008
Speed RMS: 1.119



Old Processing (all trusted):
Direction RMS: 18.992

2008 KNMI Processing
Rain Free (all trusted buoys)

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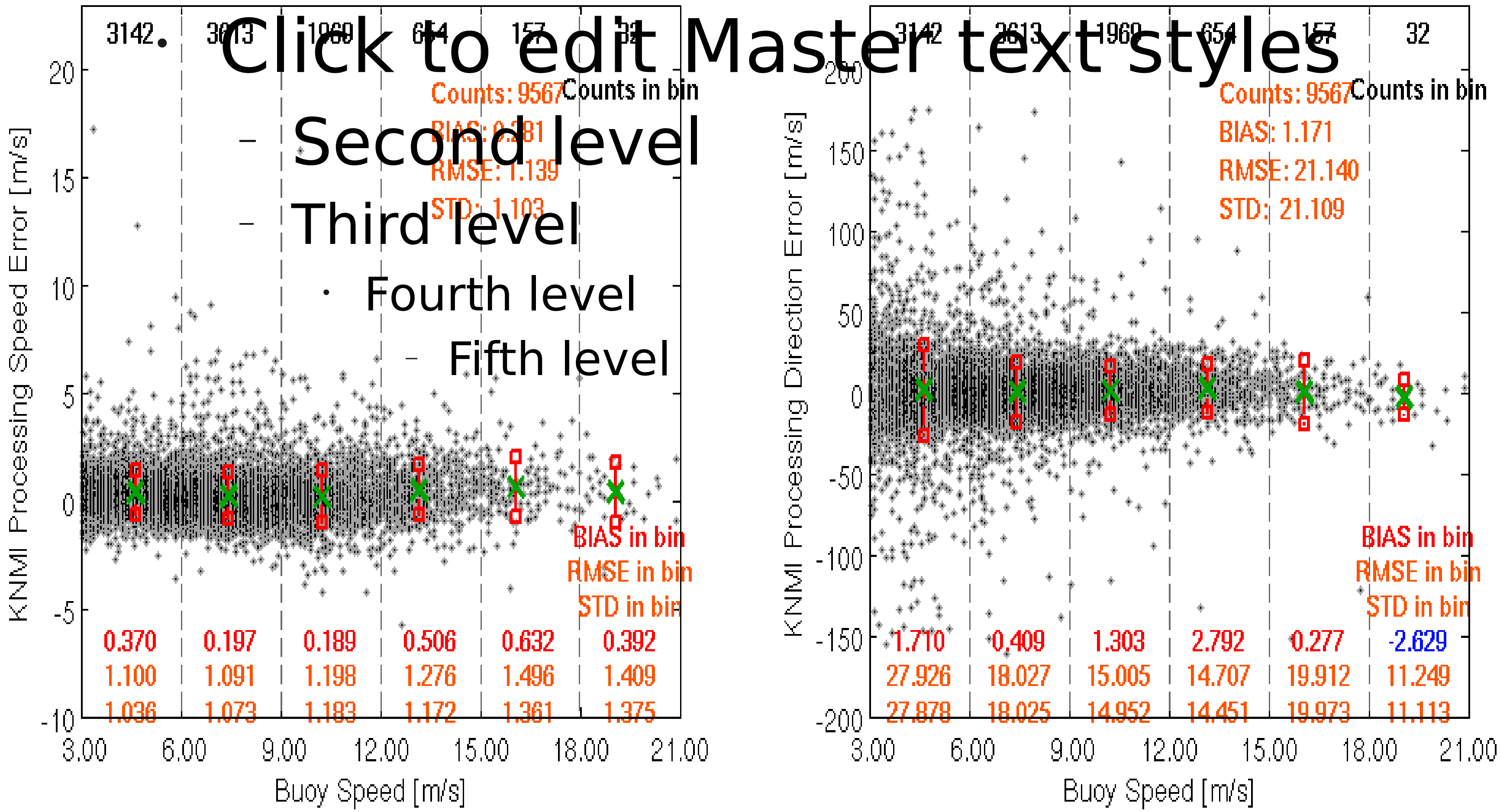
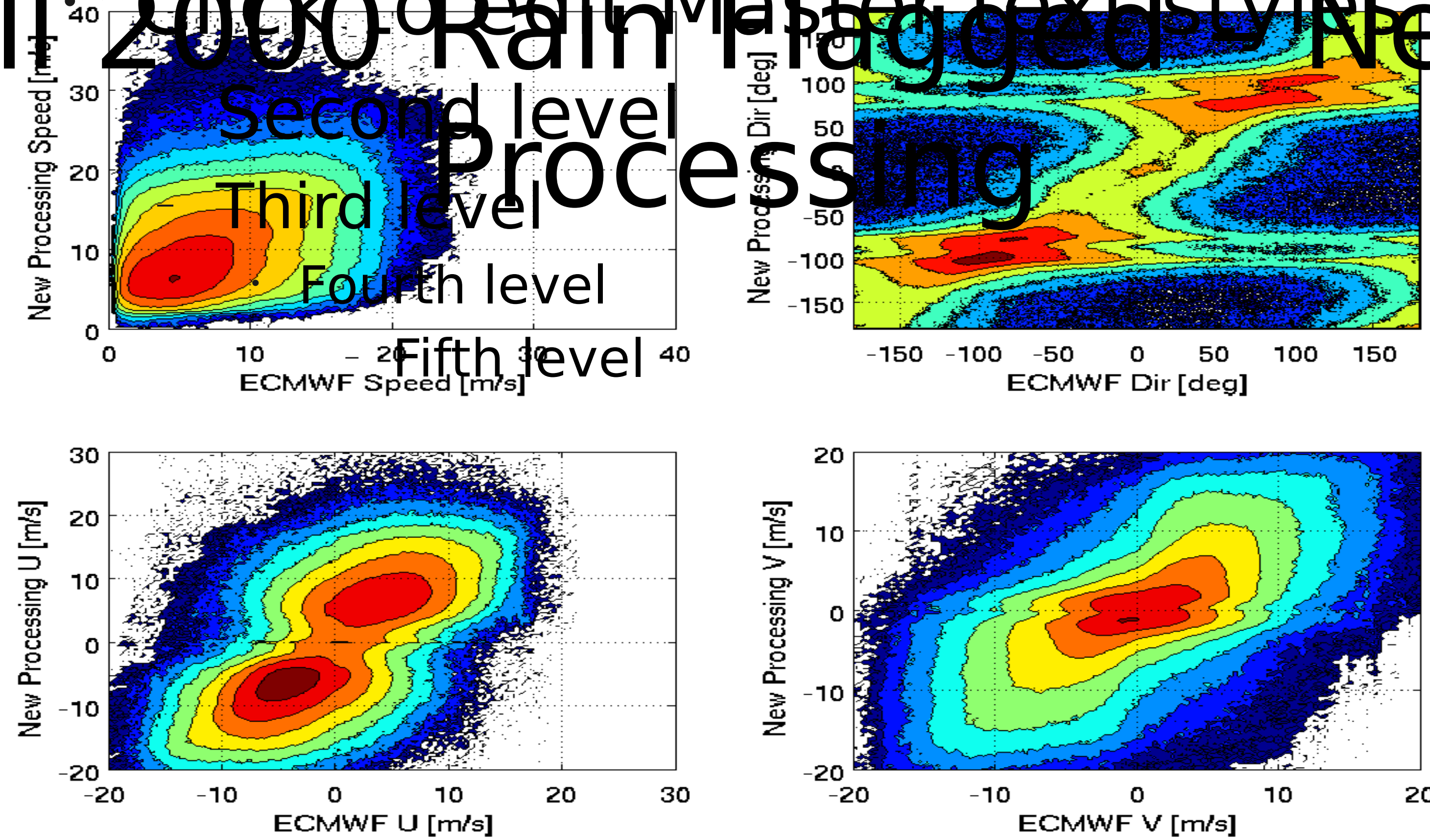


2D Histograms Compared to ECMWF

All 2000 Rain Flagged - New Processing

- Click to edit Master text styles
  - Second level
    - Third level
      - Fourth level
        - Fifth level



2D Histograms Compared to ECMWF

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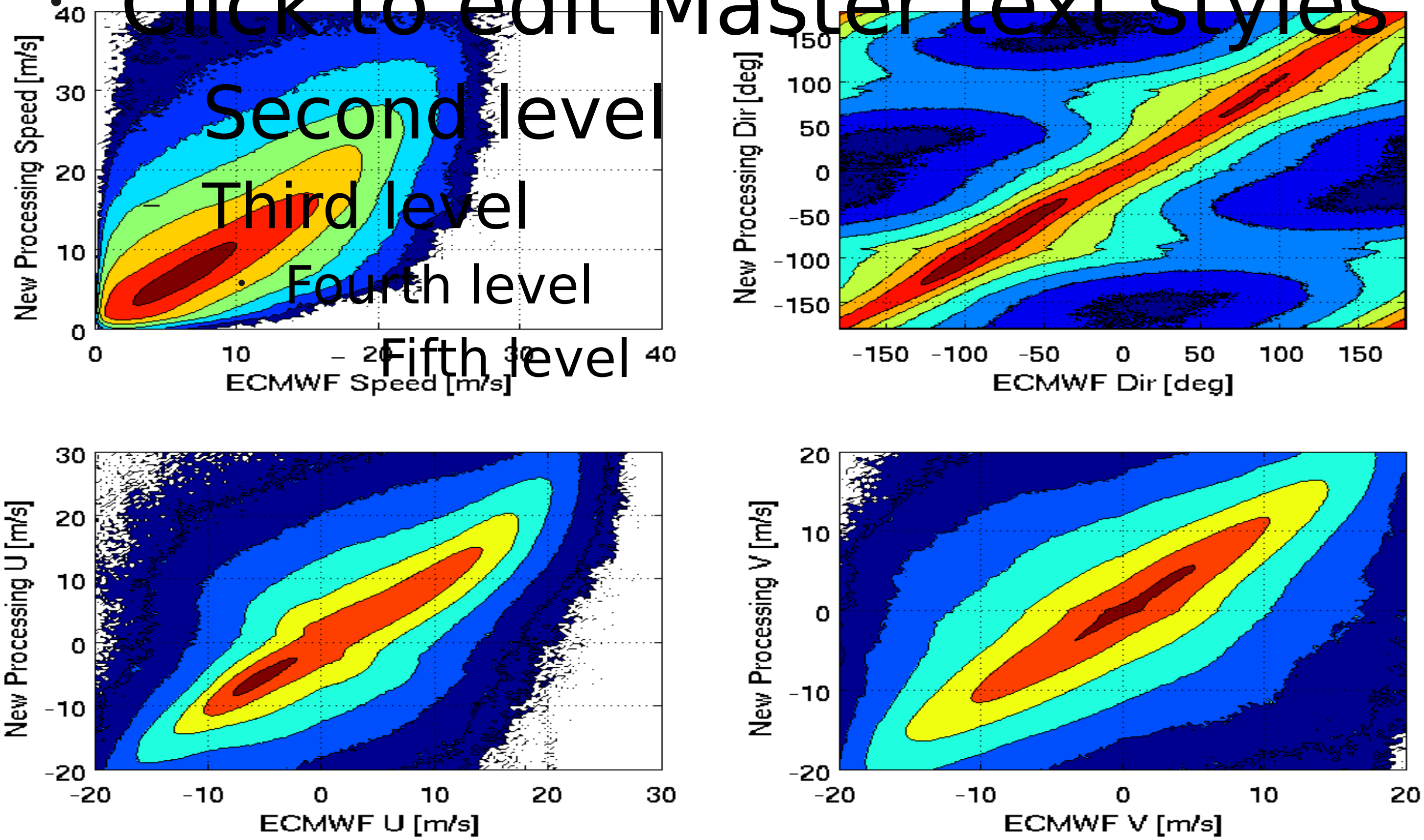
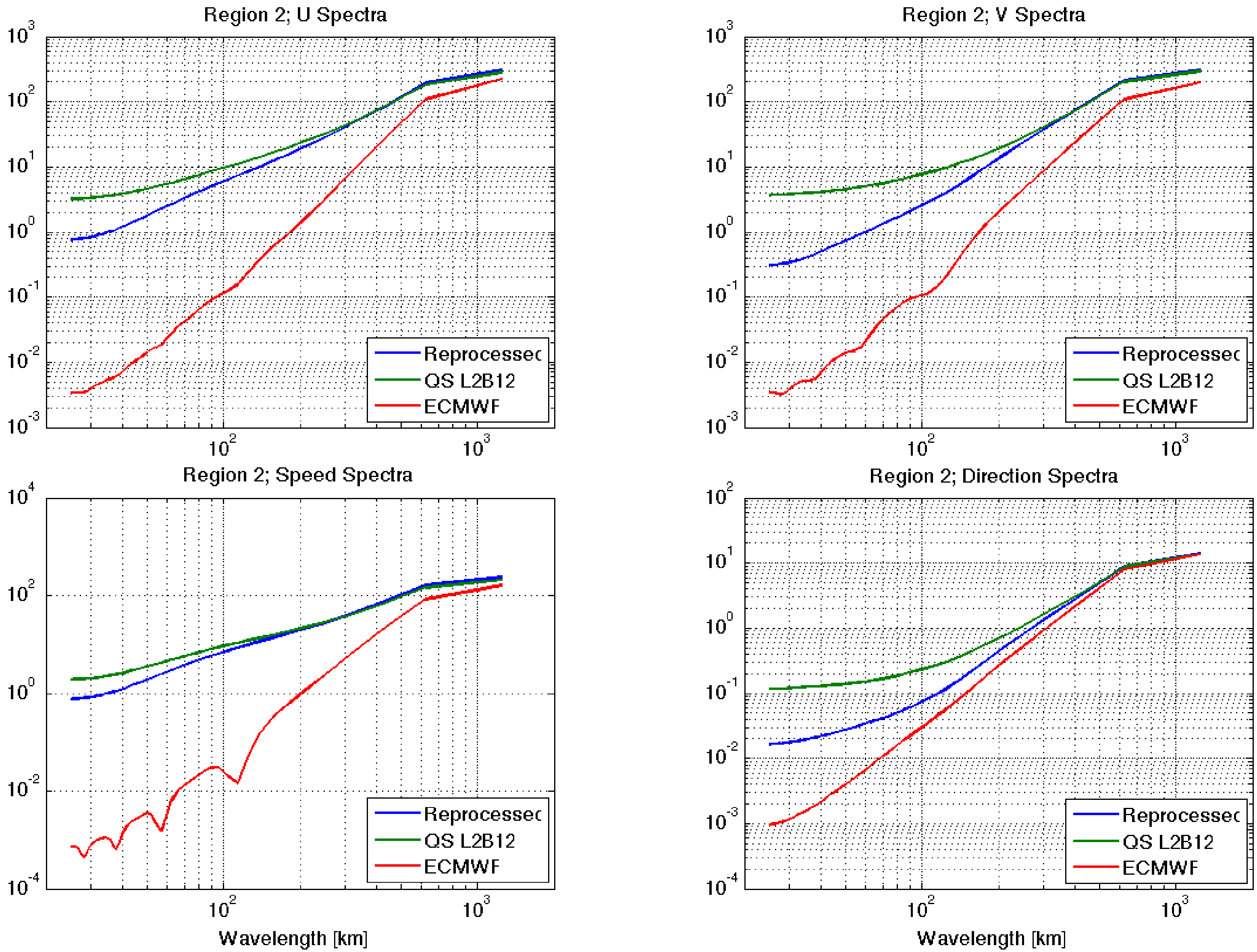
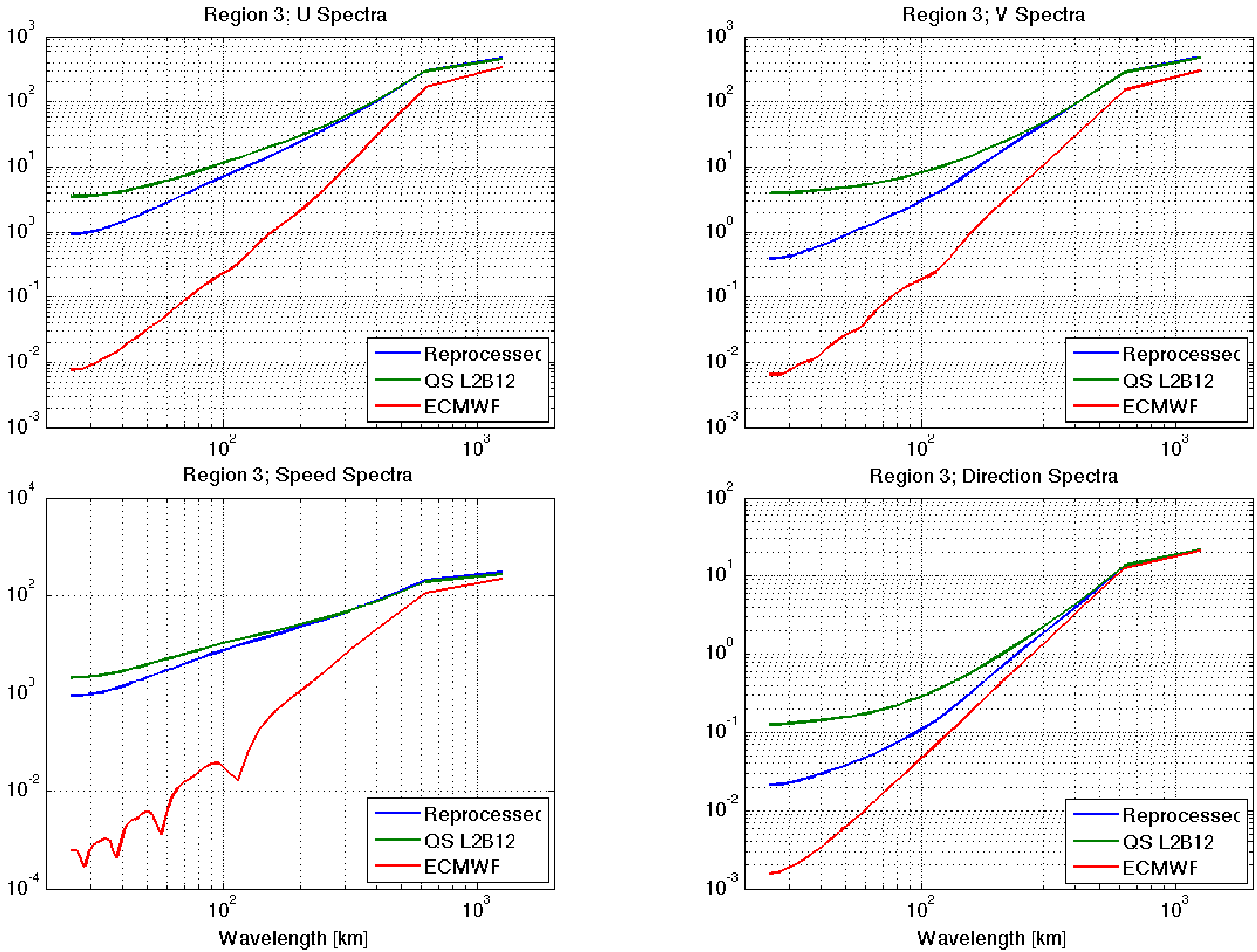
        - Fifth level



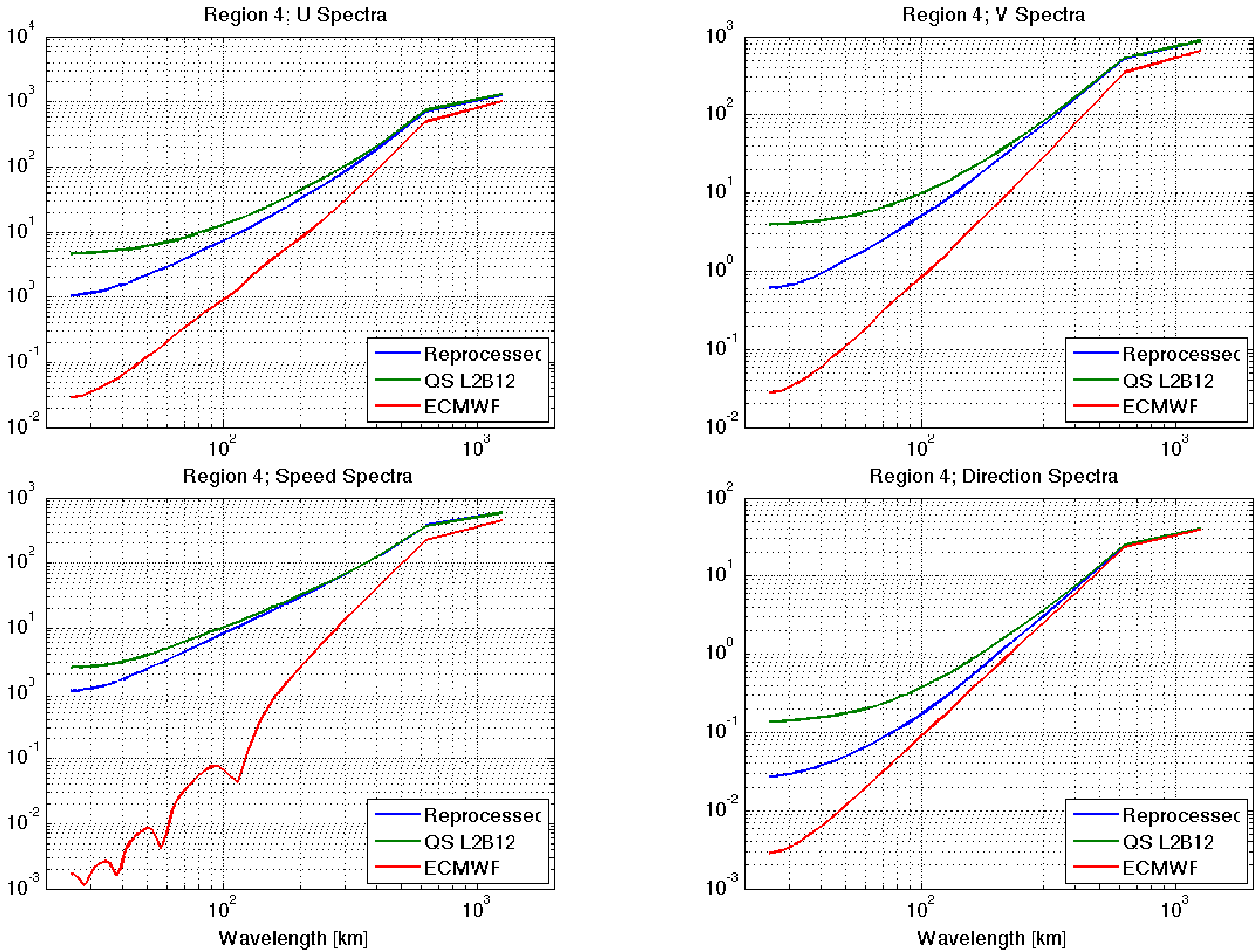
Spectra; All 2008; Region 2



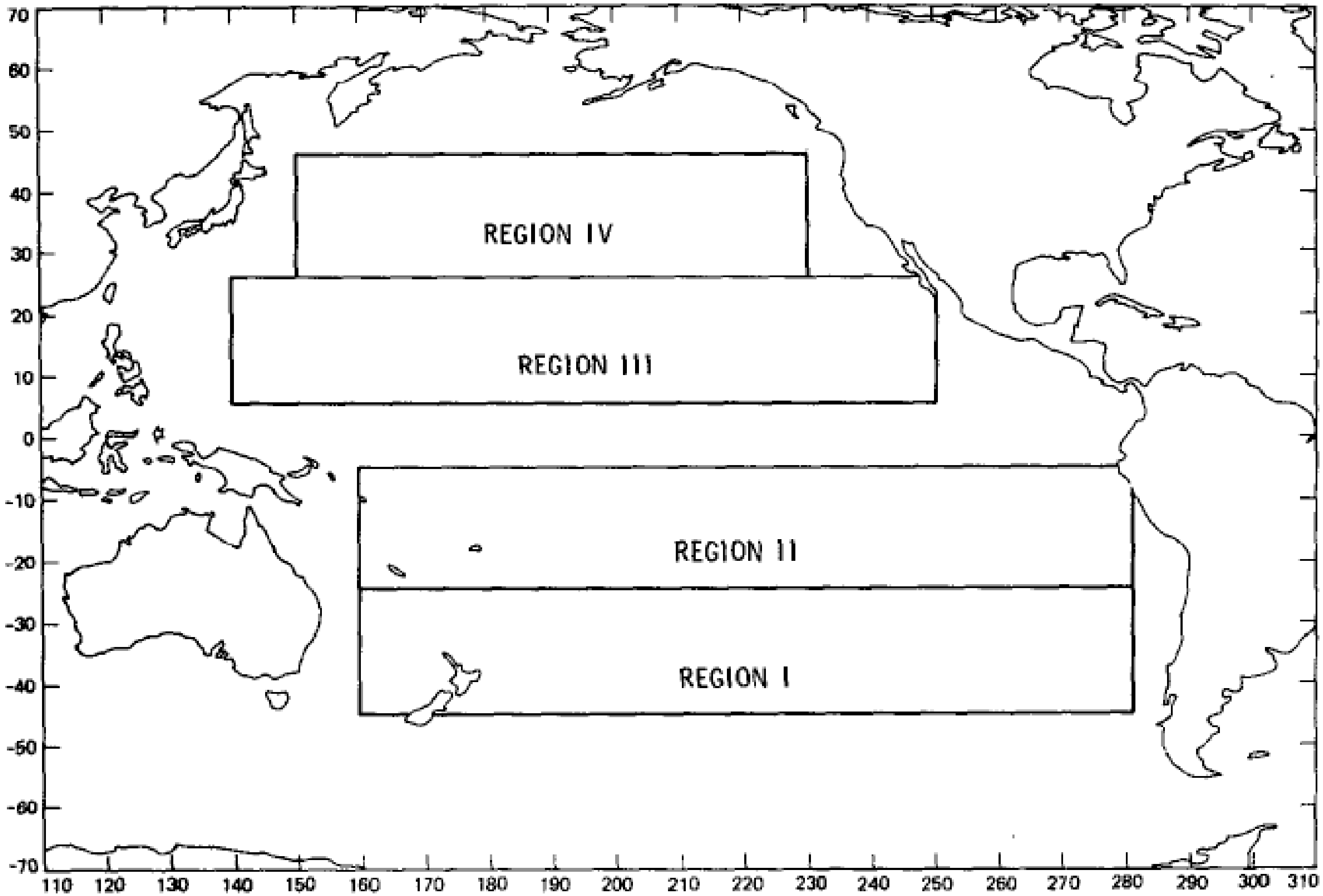
Spectra; All 2008; Region 3



Spectra; All 2008; Region 4

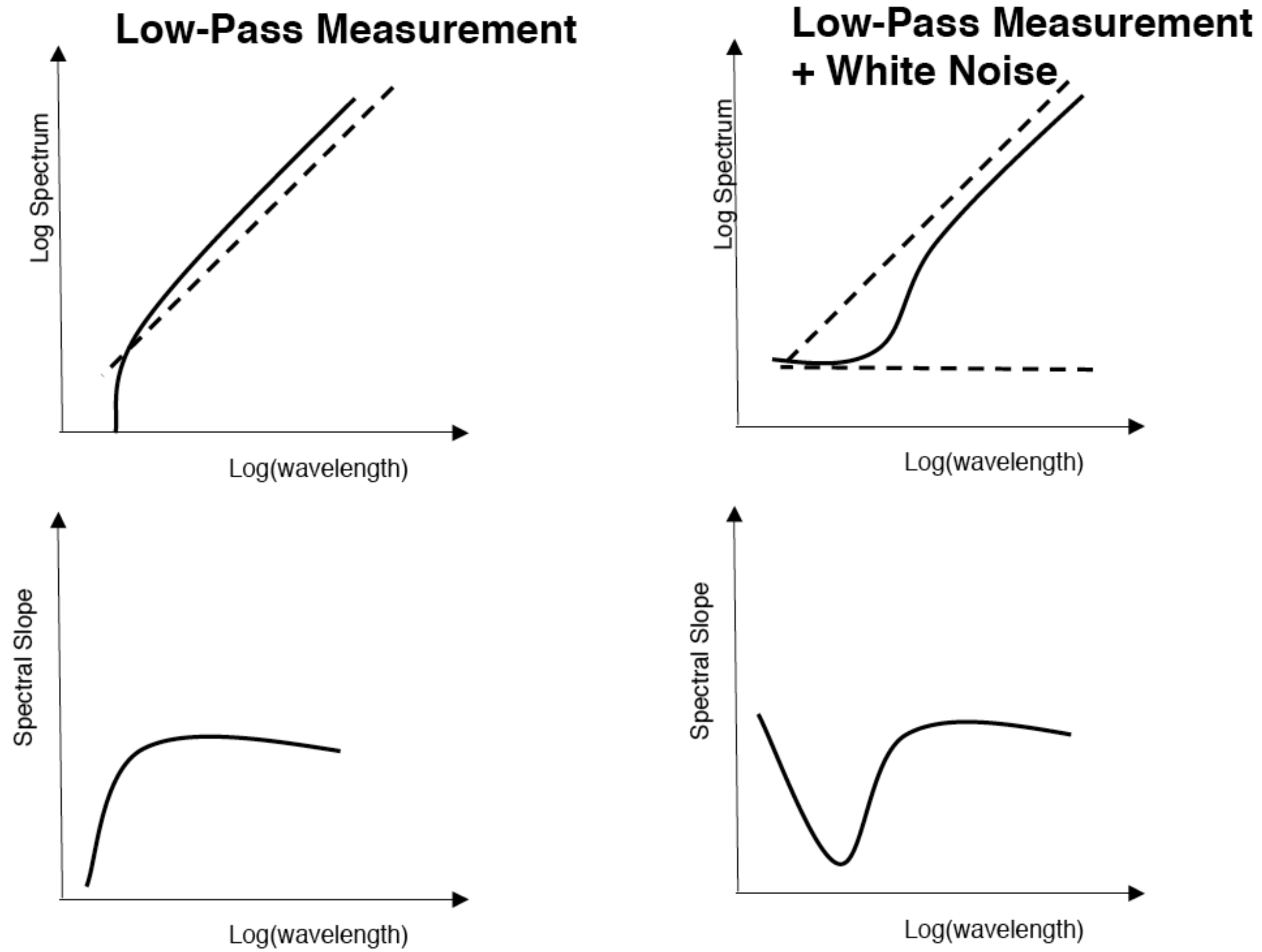


Regions for Computing Spectra



Freilich and Chelton, Journal of Physical Oceanography, 1

What to Expect for Spectra



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