Quality Control of INSTANT ADCP Velocity

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For the bottom line of what thresholds I recommend to process the INSTANT ADCP data – see Table 2 in the Conclusions!

1. Introduction:

It was determined that additional quality control (QC) was required for the moored ADCPs deployed as part of INSTANT over and above the "Percent Good" threshold approach described by RDI. For the upward-looking ADCPs used in INSTANT, it is the surface reflection that contaminates the upper most bins, and hence the main premise of any QC operation is to automate as much as possible the removal of those cells (bin x time) that are bad, while retaining as much of the "good" valuable surface-most data as possible.

2. QC Procedure Description:

The QC procedure that is described here is based on that implemented by the U.S. National Data Buoy Center, MI, and detailed in Crout et al. (2005). The NDBC QC procedure was compiled based on Ocean Observer 38 kHz and Workhorse 75 kHz ADCPs for deployment on oil rigs in the Gulf of Mexico. ADCPs deployed as part of INSTANT were Workhorse Longranger 75 kHz and 300 kHz: different thresholds were needed for the Correlation Magnitude test (4) dependent on ADCP frequency, but for other tests (as discussed below) the thresholds recommended in Crout et al., (2005) were found to be fairly good.

The NDBC procedure consists of 6 tests and for each test, data in each bin are flagged fail, suspect or pass dependent on certain threshold values (Table 1a). For the INSTANT data QC, I took the conservative approach and eliminated the "suspect" category and designated these cases as "fail".

For tests 1 through 5, the tests are implemented individually (0 = pass; 1= fail) for each cell, and then the results summed. A "profile check" is then undertaken for each cell where if the sum is ≥ 2 (i.e. the cell has failed 2 out of 5 tests) the cell is eliminated. Test 6 is a surface detection test as defined by the echo intensity designed to eliminate those sections of the profile that are obstructed. The results of the echo intensity test impact the bins beyond where it fails, as a fail is propagated to all affected bins up to the last bin. Thus, rejection of a cell can occur for one of two reasons:-

1. Two out of the five tests that comprise the summation of tests 1 to 5 fail (the OTfail).
2. Failure of the echo amplitude test (EAfail)

Hence, in the following assessment and figures, the relevant diagnostics <u>for each bin</u> are
a) For threshold parameters in Tests 1 to 5

1. percent where the individual test contributes to the number of OTfail
2. percent where that OTfail contributes to the total number of failures (OTfail + EAfail)

b) For threshold parameters in Tests 6

1. percent where the EAfail contributes to the total number of failures (OTfail+EAfail)

In the following analysis, for each of the described mooring deployment cases, I implemented the QC procedure using the "standard" thresholds for the WH300 kHz (Table 1b) and the LR 75 kHz (Table 1c), which except for allowing higher speeds (test 5) are the same as NDBC (Table 1a). Then for each individual test, I tried four different threshold criteria and assessed the impact on number of cell failures (as defined above). This method assumes that each test is independent of the other, which is not strictly correct. For instance, the Percent Good diagnostic is dependent on the correlation magnitude (test 3) and error velocity (test 1), as well as the minimum theoretical standard deviation to be tolerated, as given during instrument set-up. Nonetheless, rather than undertake a 6-dimensional cost analysis, the approach here is to simply assess what impact each of these tests has on the QC of the INSTANT data, and how our test threshold criteria may differ from that determined by NDBC. So, in the event that there is little distinguishable difference in the velocity field produced for each of the threshold criteria, my approach was to go with the NDBC choice.

	1. Error Velocity	2. Percent Good	3. Correlation Magnitude	4. Vertical velocity	5. horizontal velocity	6. echo intensity
a) NDBC	Erv ≤15 cm/s	> 25% (38kHz) > 10% (75kHz)	3 of 4 cmag values > 110 (38kHz) 3 of 4 cmag values > 64 (75 kHz)	Difference ≤ 30 cm/s	Total velocity magnitude ≤ 125 cm/s	No rise in any beam is >30 counts
b) standard (300 kHz)	≤15 cm/s	> 10%	>110	≤ 30 cm/s	≤ 200 cm/s	30 counts
c) standard (75 kHz)	≤15 cm/s	> 10%	>64	≤ 30 cm/s	≤ 200 cm/s	30 counts
d) LBK-E (WH300 kHz)	**≤15 cm/s**	**> 50%**	**>110**	**≤ 20 cm/s**	**≤ 200 cm/s**	**30 counts**
e) LBK-E (CSIRO)	≤20 cm/s	>80%	110	≤20 cm/s	≤150 cm/s	30 counts
f) OMB-N (LR 75 kHz)	**≤15 cm/s**	**> 50%**	**>64**	**≤ 20 cm/s**	**≤ 200 cm/s**	**25 counts**
g) OMB-N (CSIRO)	≤13 cm/s	>80%	115	≤15 cm/s	≤150 cm/s	20 counts
h) OMB-S (LR75 kHz)	**≤15 cm/s**	**> 50%**	**>64**	**≤ 20 cm/s**	**≤ 200 cm/s**	**25 counts**
i) OMB-S (CSIRO)	≤60 cm/s	>80%	110	≤60 cm/s	≤175 cm/s	20 counts

Table 1: Data Quality Control Tests and threshold criteria used to assess a "pass" of ADCP data.

3. Implementation of QC Procedure:

Case 1: Lombok East Deployment 2 (300 kHz Workhorse-ADCP)

For the WH300 kHz used in Lombok East Deployment 2 there are 11 depth bins and 26188 time realizations. The average, standard deviation and range values from the Lombok East deployment 2 for the parameters used in each QC test versus ADCP bin are shown in Figure 1. This helps us to implement a range of test thresholds that might be realistic and also helps guide relevant choices for QC thresholds to use for our INSTANT conditions and ADCPs.

Starting with the EA test 6 (Appendix Figure 1a), threshold choices for the difference values between each bin of 15, 20, 25 and 30 counts, all result in ~ 100% failure of bins 10 and 11, and

97% of failures in bin 9. There is little difference in percent failure in Bin 7 (66-70%) and Bin 8 (~87 – 89%) for each threshold, and there are no EAfail below Bin 7. Suggest Test 6 threshold of 30 counts, as used by NDBC.

As noted above, the percent good (Appendix Figure 1b), correlation magnitude (Appendix Figure 1c) and error velocity (Appendix Figure 1d) fields are related. For all threshold values (10%, 30%, 50% and 80%), the percent good contributes ~100% to OTfails in bins 6-11, although because of the EAfail dominance, this test contributes to only 2-3% of total failures in bins 8-11. Bins 6-7 show similar numbers for each threshold. Suggest using 50% percent good, and cmag of 110 (a choice primarily based on mean and statistics from Figure 1). The suitable choice for the error velocity threshold is a little more difficult as there is little difference between the threshold values, most contributing ~ 1% total fails in bins 7-11, and 5-20% in bin 6. However, in terms of absolute numbers, this amounts to rejection of at most ~50 cells (i.e. 1 days data), and generally much less. Stick with NDBC choice of Error velocity threshold of 0.15.

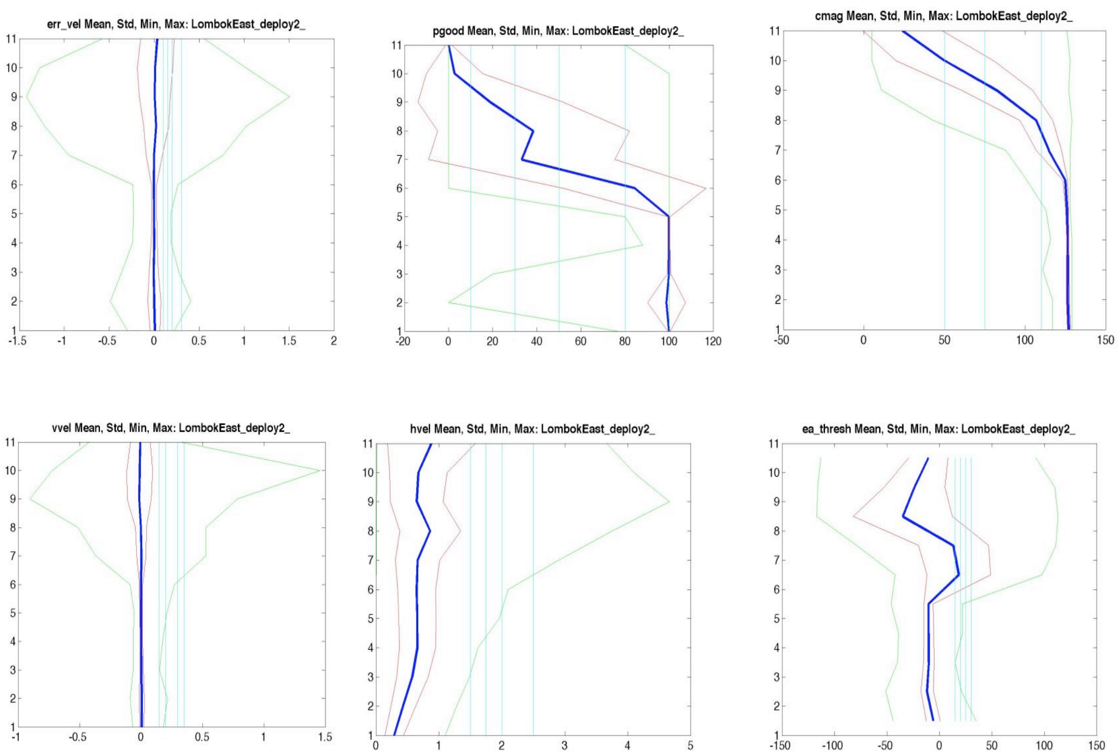

Figure 1: Mean (thick blue line), standard deviation (red lines) and minimum (green) and maximum (green line) of the a) error velocity; b) percent good; c) correlation magnitude; d) vertical velocity; e) horizontal velocity and f) echo amplitude for the Lombok East Deployment 2 WH300 kHz ADCP versus bin. The threshold values used in each test parameter are marked by the cyan lines in panels a) to f).

I found the implementation of the Vertical Velocity test as described by NDBC a little confusing. It notes that " the vertical velocity test is applied by comparing the vertical velocity in each bin to a threshold value", however the test itself is described as determining if the *difference* is less than or equal to the threshold value of 30 cm/s. The difference of what? Adjacent bins? Figure 1 suggests that an appropriate threshold value might be 20 cm/s, which still only amounts to rejection of 5-20 cells in bins 6-11 (Appendix Figure 1e).

For the Horizontal Velocity (current speed) test, the NDBC threshold was only 0.5 m/s, whereas speeds in these Indonesian passages average 0.5 m/s and tidal current speeds of ~ 175 cm/s and above are not totally unrealistic (see average and max speed in Figure 1). Threshold current speeds below 175 m/s impact bin 5 (Appendix Figure 1f), and are the only test that do so, although the number of bins rejected is small. A threshold current speed of 200 cm/s is recommended for the Indonesian region.

Recommended thresholds for the QC tests of INSTANT ADCP data are found in Table 1d.

A comparison of the Meridional Velocity for Lombok East – deployment 2 as determined from the recommended thresholds (Table 1d), and those applied to the CSIRO Nov07 data set (Table 1e) are shown in Figure 2. Obvious differences occur in bins 7-10, where the revised thresholds retain more cells. Note that both these figures show velocity where depths shallower than 2 m have been cutoff.

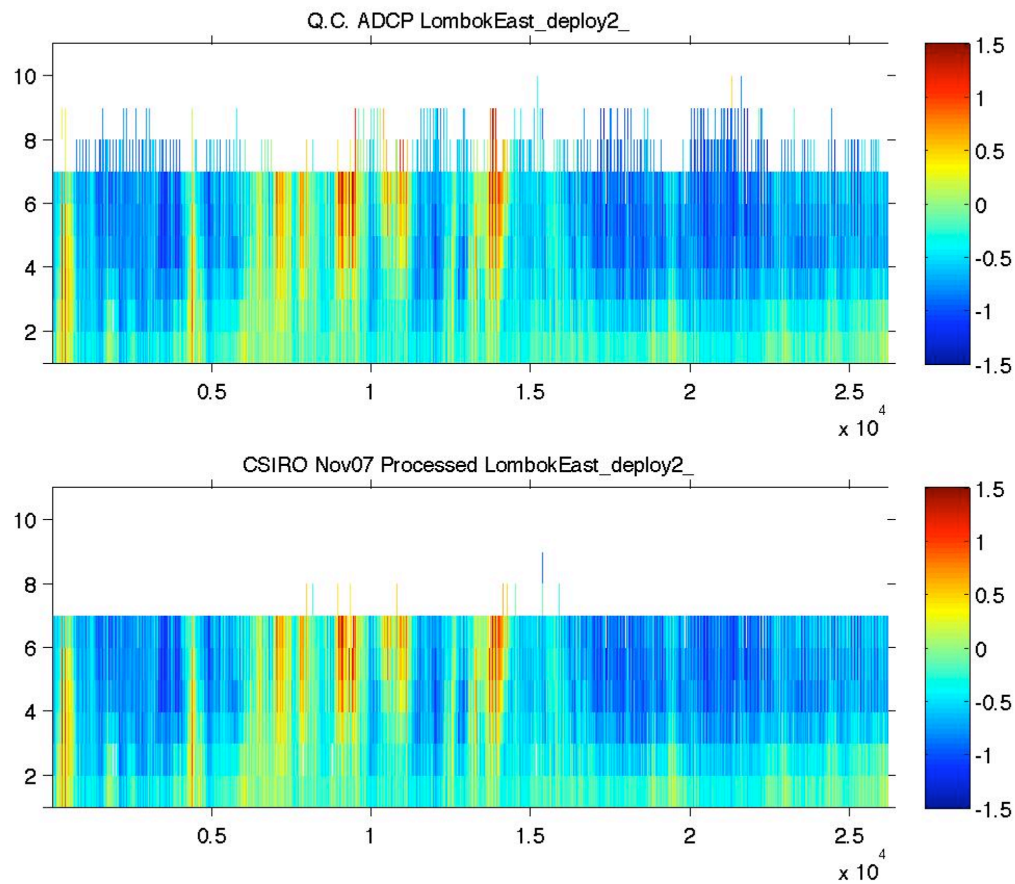

Figure 2: Comparison of Meridional Velocity in Lombok East – Deployment 2 determined after implementing the ADCP QC thresholds (Table 1c), and that from the Nov07 data set (Table 1d).

Case 2: Ombai North Deployment 2 (75 kHz Long Ranger ADCP):-

For the LR 75 kHz used in Ombai North Deployment 2 there are 40 depth bins and 25017 time realizations. The average, standard deviation and range values from the Ombai North deployment 2 for the parameters used in the QC test versus ADCP bin are shown in Figure 3.

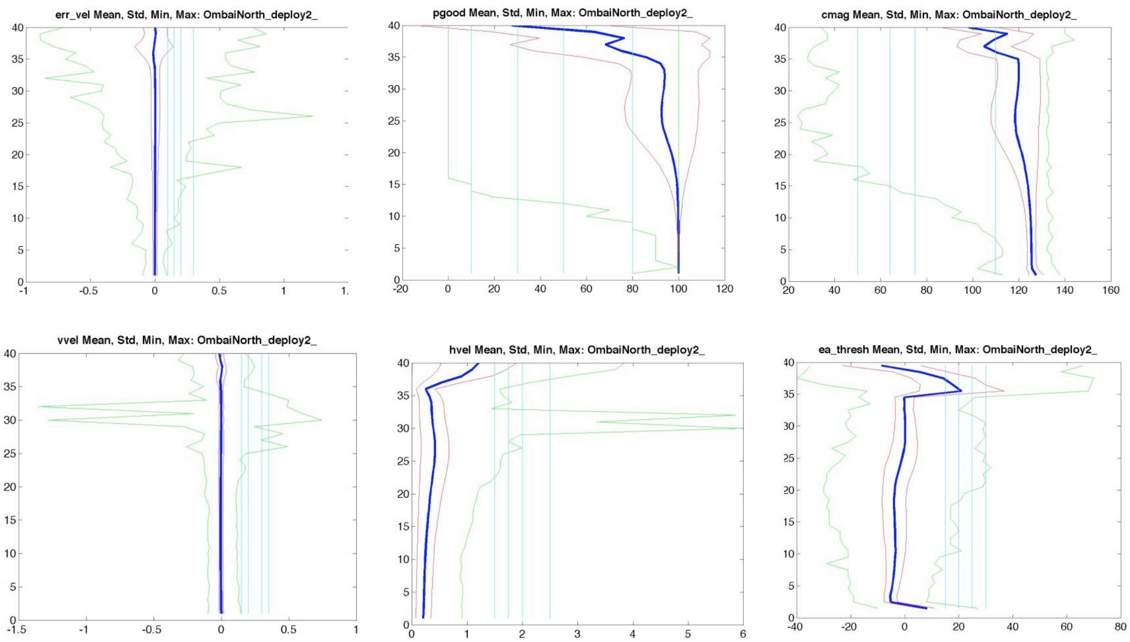

Figure 3: Mean (thick blue line), standard deviation (red lines) and minimum (green) and maximum (green line) of the a) error velocity; b) percent good; c) correlation magnitude; d) vertical velocity; e) horizontal velocity and f) echo amplitude for the Ombai North Deployment 2 LR 75kHz ADCP versus bin. The threshold values used in each test parameter are marked by the cyan lines in panels a) to f).

As for Lombok, in the Ombai North deployment the EAfail mainly occurs in the upper most bins 36-40 (Appendix Figure 2a). In bins 30-35, the EAfail can vary from 2% (for a threshold of 30) to ~47% (for threshold of 15). Decided that a threshold of 25 is good (based on stats in Figure 3, and compromise from Appendix Figure 2a).

The percent good on the WH300 stayed mostly at 100% until the very top most bins where it dropped rapidly (Figure 1), compared to the LR75 field (Figure 3) which drops off to ~90% at the middle bin 20 (with larger std and minimum values of 0% evident). Surprisingly though, the failure rate is relatively insensitive to the choice of threshold values (Appendix Figure 2b), with the percent good in the top most bins 36-40 responsible for ~ 1% of total fails, and ~70% in bins 30-34. This insensitivity to the thresholds from 10% to 80% suggests that the percent good values that are rejected are likely near zero, and hence definitely bad! As in Lombok, the percent good occurs in nearly 100% of cases of OTfail, which means that the parameter is at least partially fulfilling the RDI role as a QC parameter! Due to the relative insensivity, decided to use 50% threshold as in the WH300 case.

The mean correlation magnitude profile (Figure 3) is similar to the percent good profile (as the two fields are related), and the NDBC recommended threshold for the LR 75 kHz of 64 seems appropriate (Appendix Figure 2c). As in Lombok, the Error velocity test (Appendix Figure 2d) and the vertical velocity test (Appendix Figure 2e) rejects few cells in terms of absolute numbers, so go with NDBC recommended value of 0.15 and 0.2 respectively.

The horizontal velocity is smaller at North Ombai (mean <0.3 cm/s, Figure 3) compared to Lombok, and the test was relatively insensitive to the range of chosen threshold values (Appendix Figure 2f), probably because they were too large. Keeping with the thought that it is not totally unrealistic for speeds within the Indonesian passages to reach 200 cm/s, this threshold value will be retained for the LR 75 kHz.

A comparison of the Zonal velocity for Ombai North – deployment 2 as determined from the recommended thresholds (Table 1f), and those applied to the CSIRO Nov07 data set (Table 1g) are shown in Figure 4. The new QC parameters remove the spurious high velocity bins in Bin 36-37, but retain some of the more realistic velocities in the surface bins.

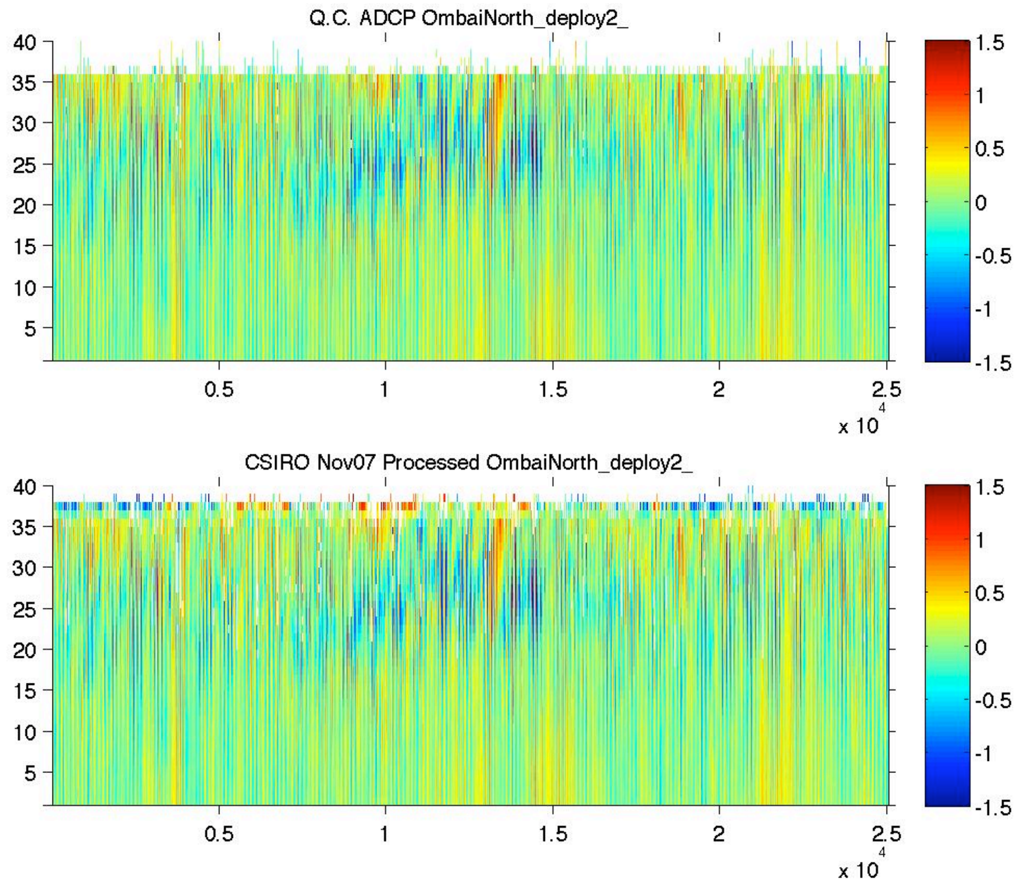

Figure 4: Comparison of Zonal Velocity in Ombai North – Deployment 2 determined after implementing the ADCP QC thresholds (Table 1f), and that from the Nov07 data set (Table 1g).

Case 3: Ombai South Deployment 2 (LR 75 kHz ADCP):-

For the LR 75 kHz used in Ombai South Deployment 2 there are 46 depth bins and 25041 time realizations. The average, standard deviation and range values from the Ombai South deployment 2 LR75 kHz for the parameters used in the QC test versus ADCP bin are shown in Figure 5.

The sensitivity of the QC thresholds on this deployment are hopefully very similar to that found during the Ombai South Deployment 2 because they both deployed LR 75 kHz ADCPs. Nonetheless, for completeness, I undertook tests of the ADCP data for this deployment and report results here (without figures). As a starting point, I use the QC thresholds as determined from the North Ombai deployment (Table 1f). Although note the structure of the means (Figure 5) are different to that of North Ombai (Figure 3). There are larger fall-offs with bin in percent good and cmag, and the current speeds are higher.

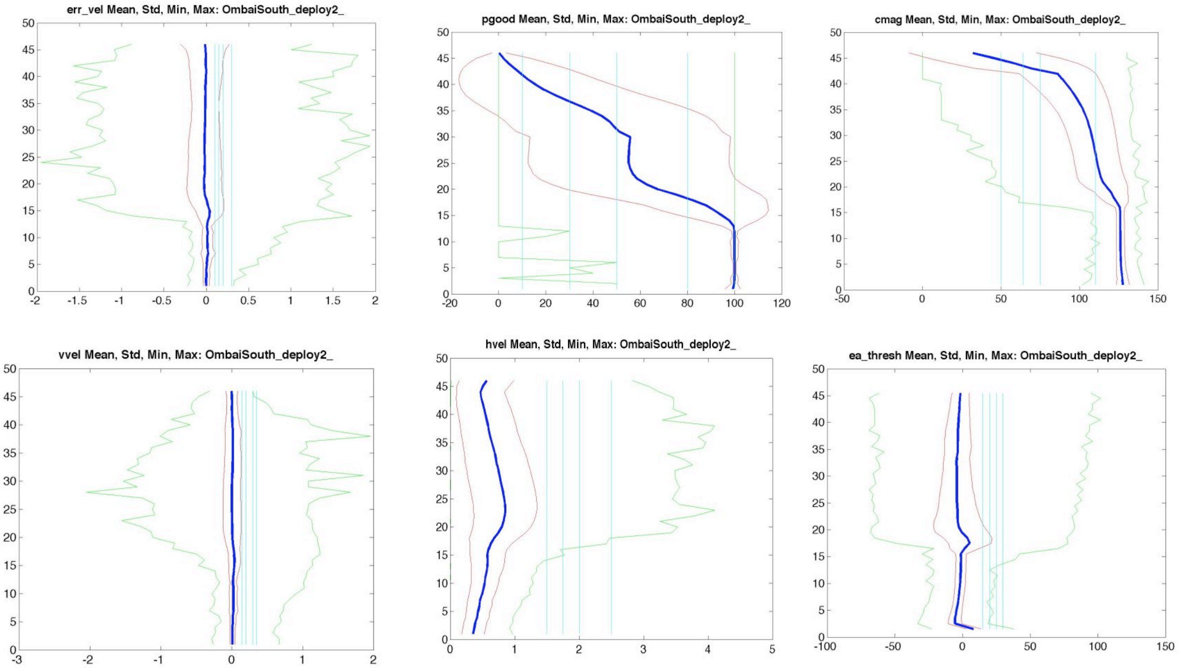

Figure 5: Mean (thick blue line), standard deviation (red lines) and minimum (green) and maximum (green line) of the a) error velocity; b) percent good; c) correlation magnitude; d) vertical velocity; e) horizontal velocity and f) echo amplitude for the Ombai South Deployment 2 LR 75kHz ADCP versus bin. The threshold values used in each test parameter are marked by the cyan lines in panels a) to f).

Implementation of the individual tests (not shown) produce a much more fragmented velocity field – but then this is likely a result of the much more dynamic conditions of the mooring location itself. The stronger current speeds cause much more blow-over, which reduces coverage of the upper bins more frequently. EAfail for a threshold of 25 results in 100% failure in bins 42-46 and 35-40% failure in bins 30-40. The OTfails in bins 30-40 are ~20% due to percent good (threshold 30%); 20% due to error velocity (threshold 0.15); 10% due to vertical velocity (threshold 0.2) and a few percent due to the other tests. The QC threshold criteria that were found appropriate for the LR 75 kHz used in North Ombaiare also suitable for the LR used in South Ombai.

A comparison of the Zonal velocity for Ombai South – deployment 2 as determined from the recommended thresholds (Table 1h), and those applied to the CSIRO Nov07 data set (Table 1i) are shown in Figure 6. Note that the Nov07 data set used an error velocity of 0.6 m/s and a vertical velocity difference of 0.6 m/s which both seem a little high. The new QC parameters retain some of the higher velocities in the surface bins. As in the other comparisons, cells where the depth < 2m have been rejected in both velocity fields.

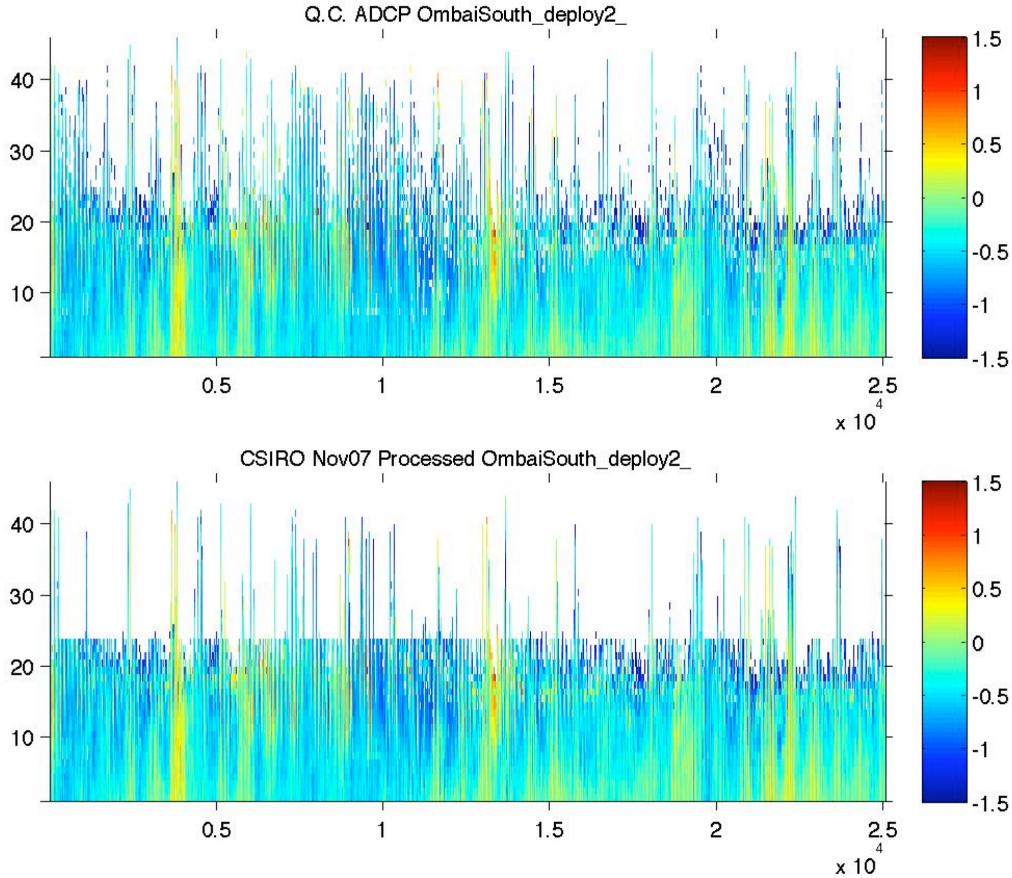

Figure 6: Comparison of Zonal Velocity in Ombai South – Deployment 2 determined after implementing the ADCP QC thresholds (Table 1h), and that from the Nov07 data set (Table 1i).

4. Conclusions:

The ADCPs deployed during the INSTANT field program were quality controlled using six tests developed by the NDBC. A variety of critical thresholds were applied for each test to determine their impact on the velocity field. The results show that it should be possible to apply a standard set of thresholds for both the WH300 kHz and the LR 75 kHz ADCPs used during the INSTANT deployment (Table 2).

ADCP Type	1. Error Velocity	2. Percent Good	3. Correlation Magnitude	4. Vertical velocity	5. horizontal velocity	6. echo intensity
WH300 kHz	**≤15 cm/s**	**> 50%**	**>110**	**≤ 20 cm/s**	**≤ 200 cm/s**	**30 counts**
LR 75 kHz	**≤15 cm/s**	**> 50%**	**>64**	**≤ 20 cm/s**	**≤ 200 cm/s**	**25 counts**

References:
Crout, R. D. Conleee, D. Gilhousen, R. Bouchard, M. Garcia, F. Demarco, M. Livingston, C. Cooper, and R. Raye. (2005). Real-time oil platform ocean current data in the Gulf of Mexico: An IOOS industry partnership success story. Abstract for AGU Mtg.

APPENDIX

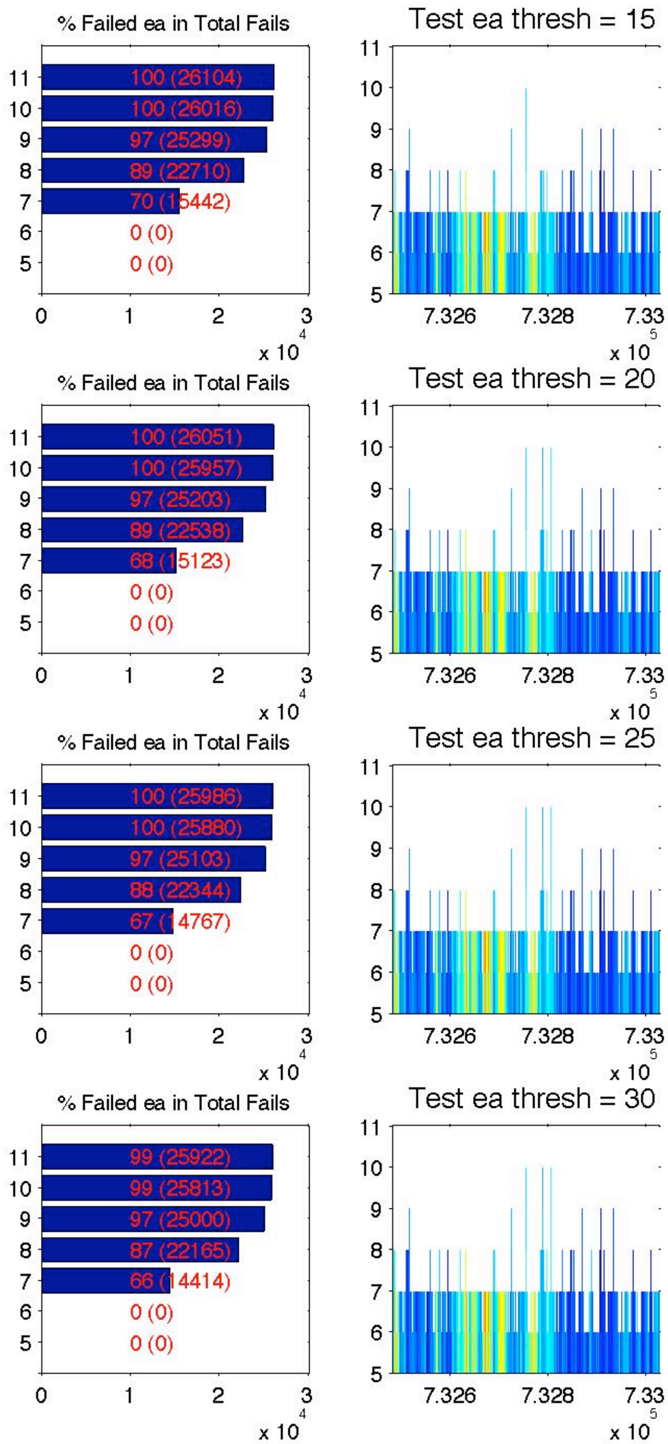

Figure 1a: Histograms of the EAtest failures (left hand panels), where P(N) indicates the percentage (P) of the number of EAfail (N) to the total number of failures in each bin and the resulting meridional velocity field (right hand panels) for the Echo Amplitude test 6 using threshold parameters of a) 15 counts; b) 20 counts; c) 25 counts and d) 30 counts.

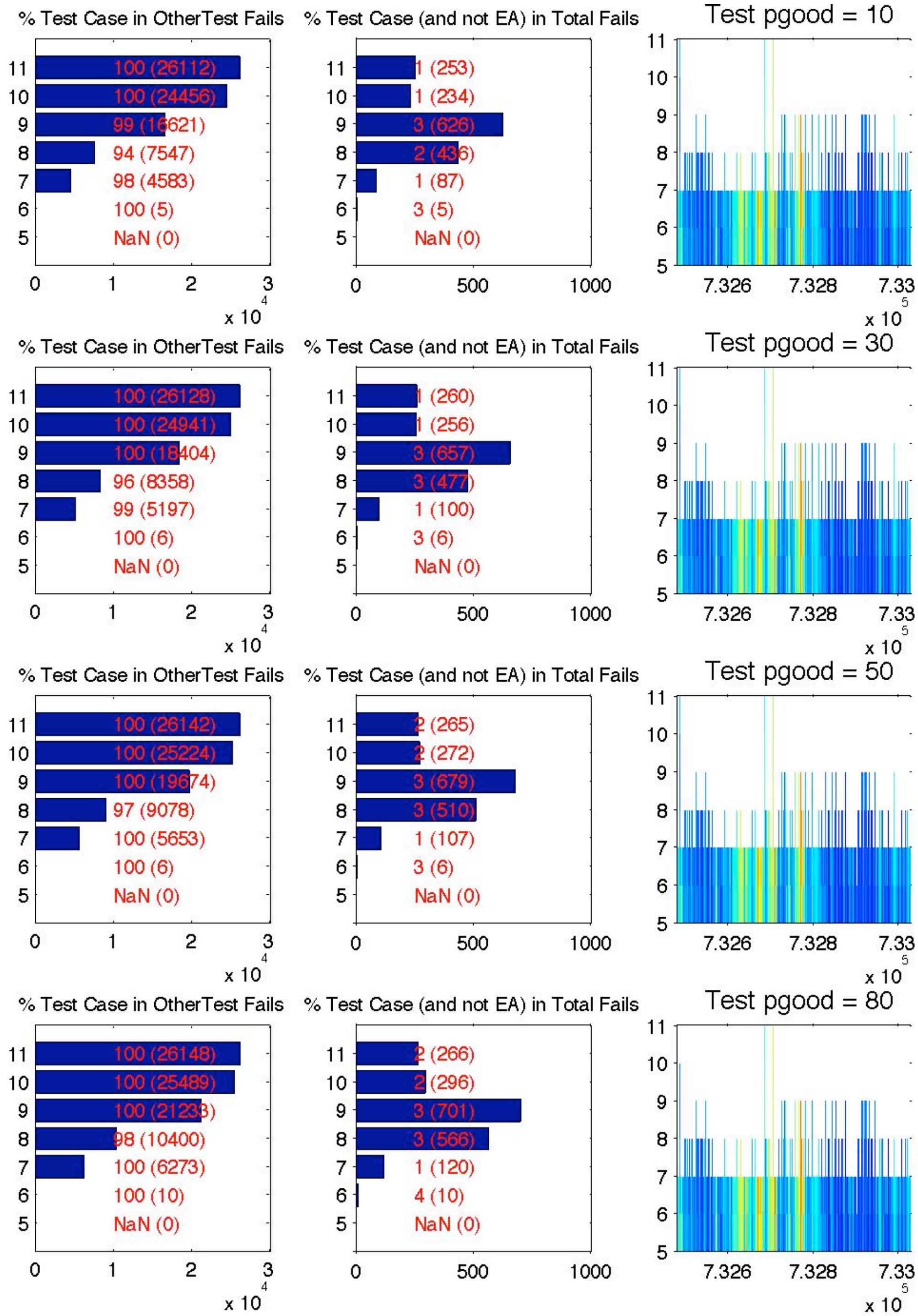

Figure 1b: Histograms of the contribution of the Percent Good (test 1) failures to the OTfails (left hand panels) and the contribution of these OTfails to the total fails (middle panels), where P(N) indicates the percentage (P) and number (N) of failures to the total number of failures in each bin and the resulting meridional velocity field (right hand panels) for threshold parameters of a) 10%; b) 30%; c) 50% and d) 80%.

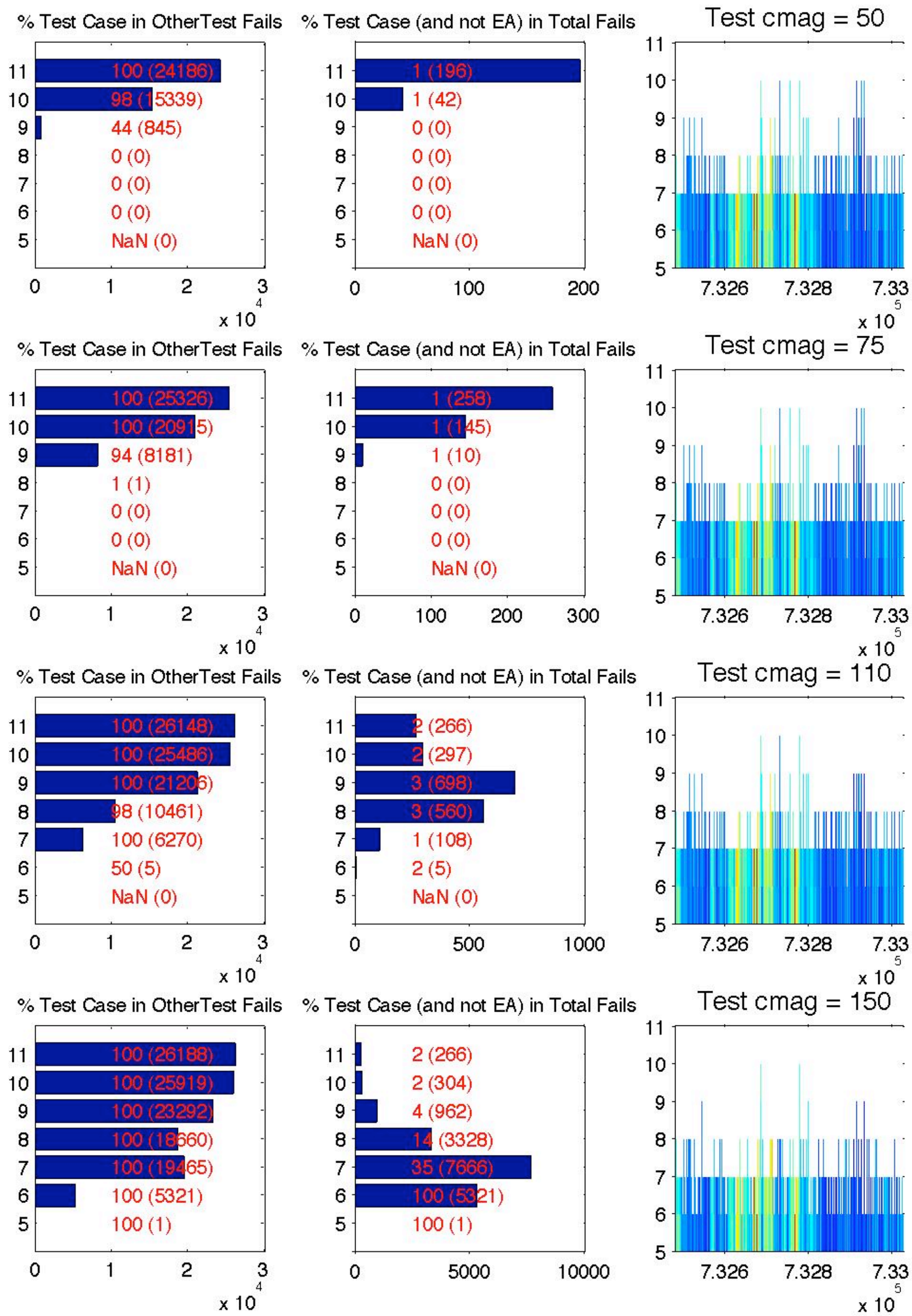

Figure 1c: Histograms of the contribution of the Correlation Magnitude (test 2) failures to the OTfails (left hand panels) and the contribution of these OTfails to the total fails (middle panels), where P(N) indicates the percentage (P) and number (N) of failures to the total number of failures in each bin and the resulting meridional velocity field (right hand panels) for threshold parameters of a) 50; b) 75; c) 110 and d) 150.

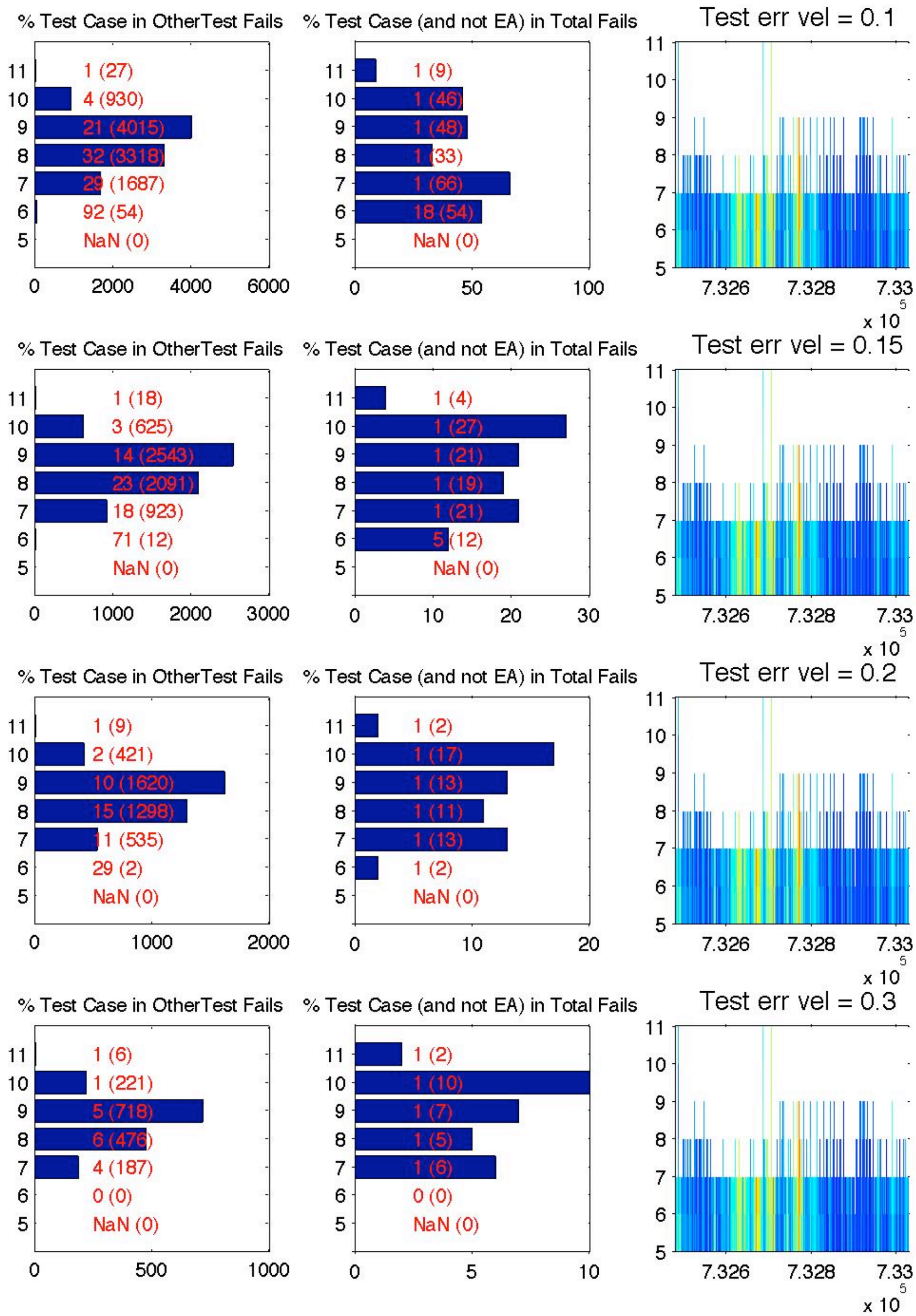

Figure 1d: Histograms of the contribution of the Error Velocity (test 3) failures to the OTfails (left hand panels) and the contribution of these OTfails to the total fails (middle panels), where P(N) indicates the percentage (P) and number (N) of failures to the total number of failures in each bin and the resulting meridional velocity field (right hand panels) for threshold parameters of a) 0.1; b) 0.15; c) 0.2 and d) 0.3 m/s.

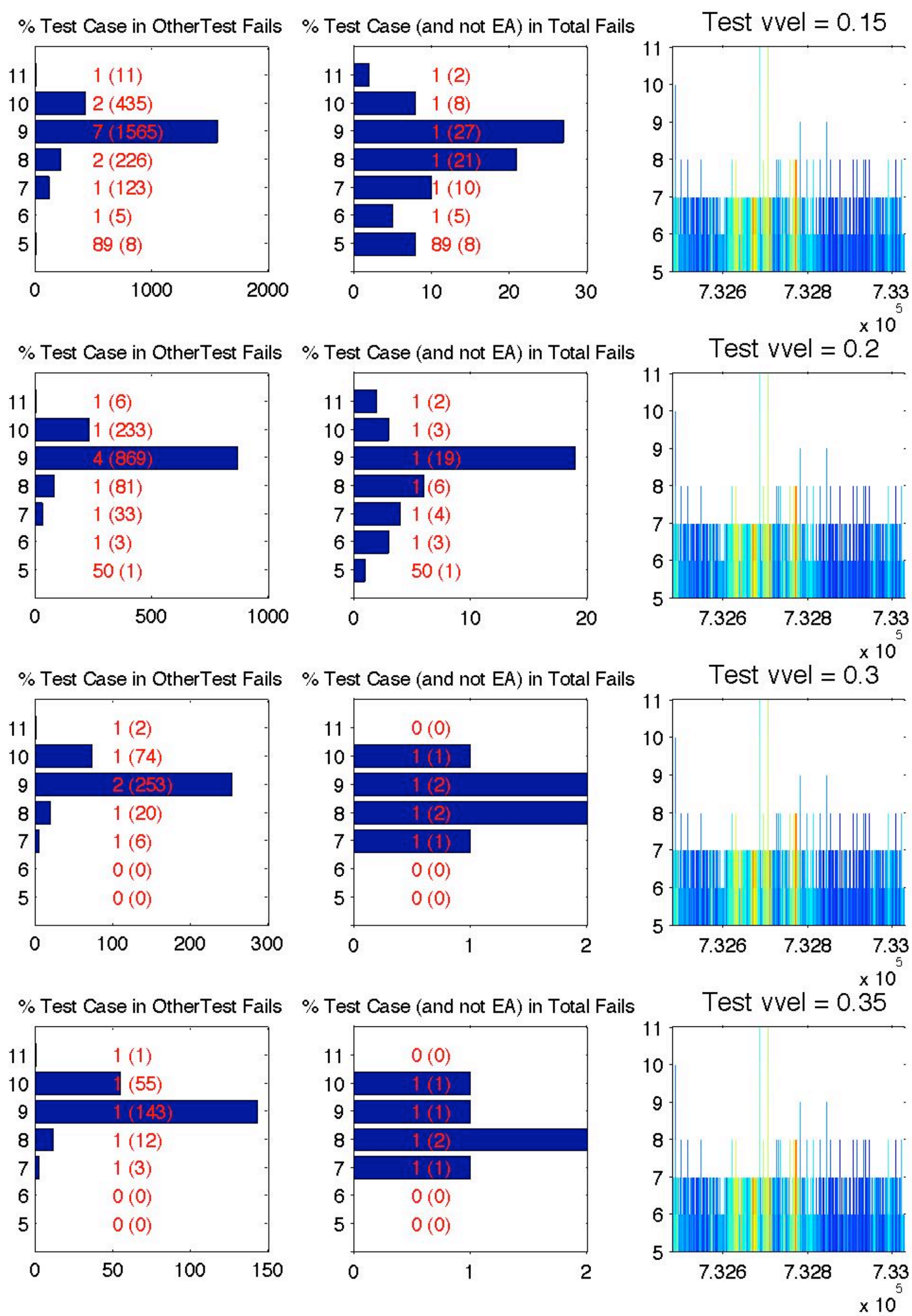

Figure 1e: Histograms of the contribution of the Vertical Velocity (test 4) failures to the OTfails (left hand panels) and the contribution of these OTfails to the total fails (middle panels), where P(N) indicates the percentage (P) and number (N) of failures to the total number of failures in each bin and the resulting meridional velocity field (right hand panels) for threshold parameters of a) 0.15; b) 0.20; c) 0.30 and d) 0.35 m/s.

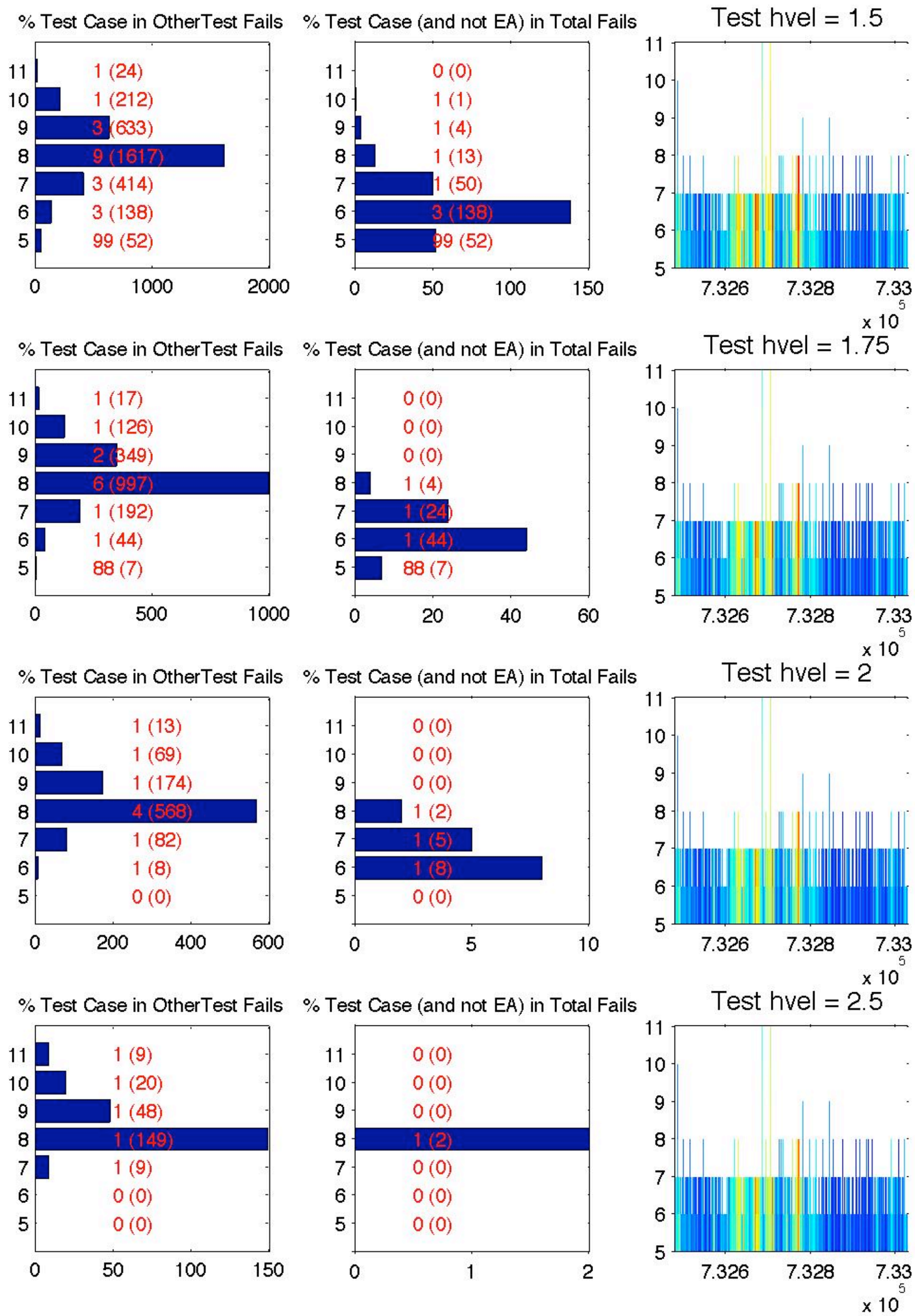

Figure 1f: Histograms of the contribution of the Horizontal Velocity (test 5) failures to the OTfails (left hand panels) and the contribution of these OTfails to the total fails (middle panels), where P(N) indicates the percentage (P) and number (N) of failures to the total number of failures in each bin and the resulting meridional velocity field (right hand panels) for threshold parameters of a) 1.5; b) 1.75; c) 2.0 and d) 2.5 m/s.

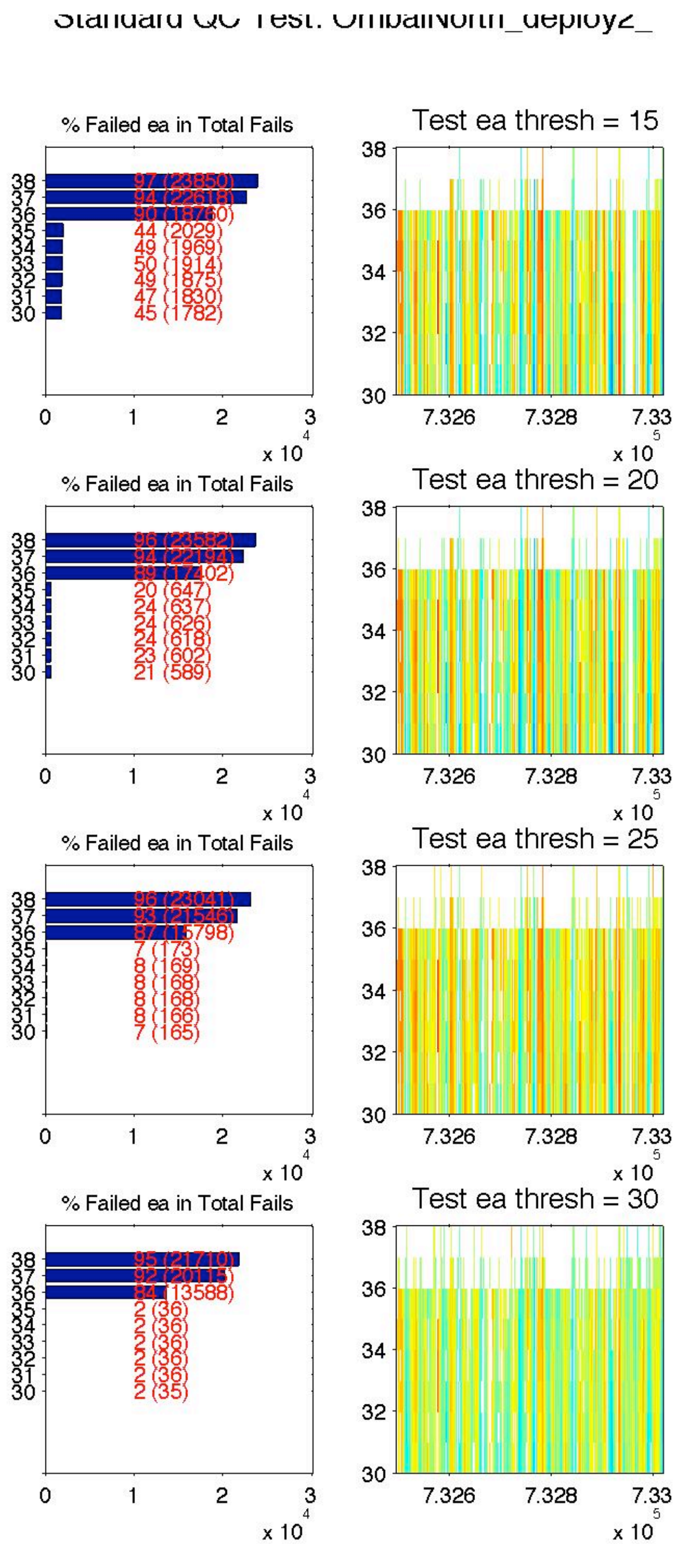

Figure 2a: Histograms of the EAtest failures (left hand panels), where P(N) indicates the percentage (P) of the number of EAfail (N) to the total number of failures in each bin and the resulting meridional velocity field (right hand panels) for the Echo Amplitude test 6 using threshold parameters of a) 15 counts; b) 20 counts; c) 25 counts and d) 30 counts.

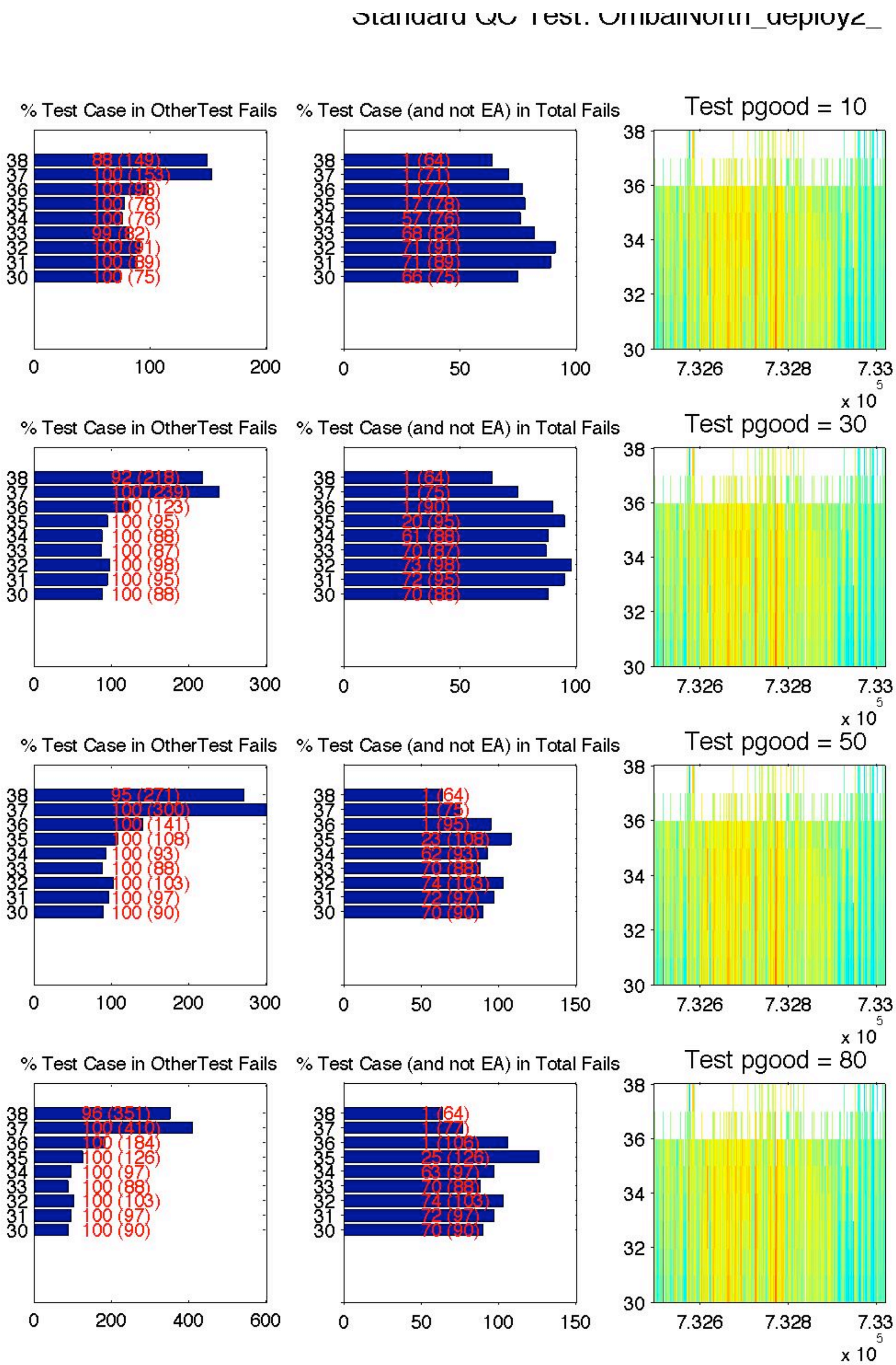

Figure 2b: Histograms of the contribution of the Percent Good (test 1) failures to the OTfails (left hand panels) and the contribution of these OTfails to the total fails (middle panels), where P(N) indicates the percentage (P) and number (N) of failures to the total number of failures in each bin and the resulting meridional velocity field (right hand panels) for threshold parameters of a) 10%; b) 30%; c) 50% and d) 80%.

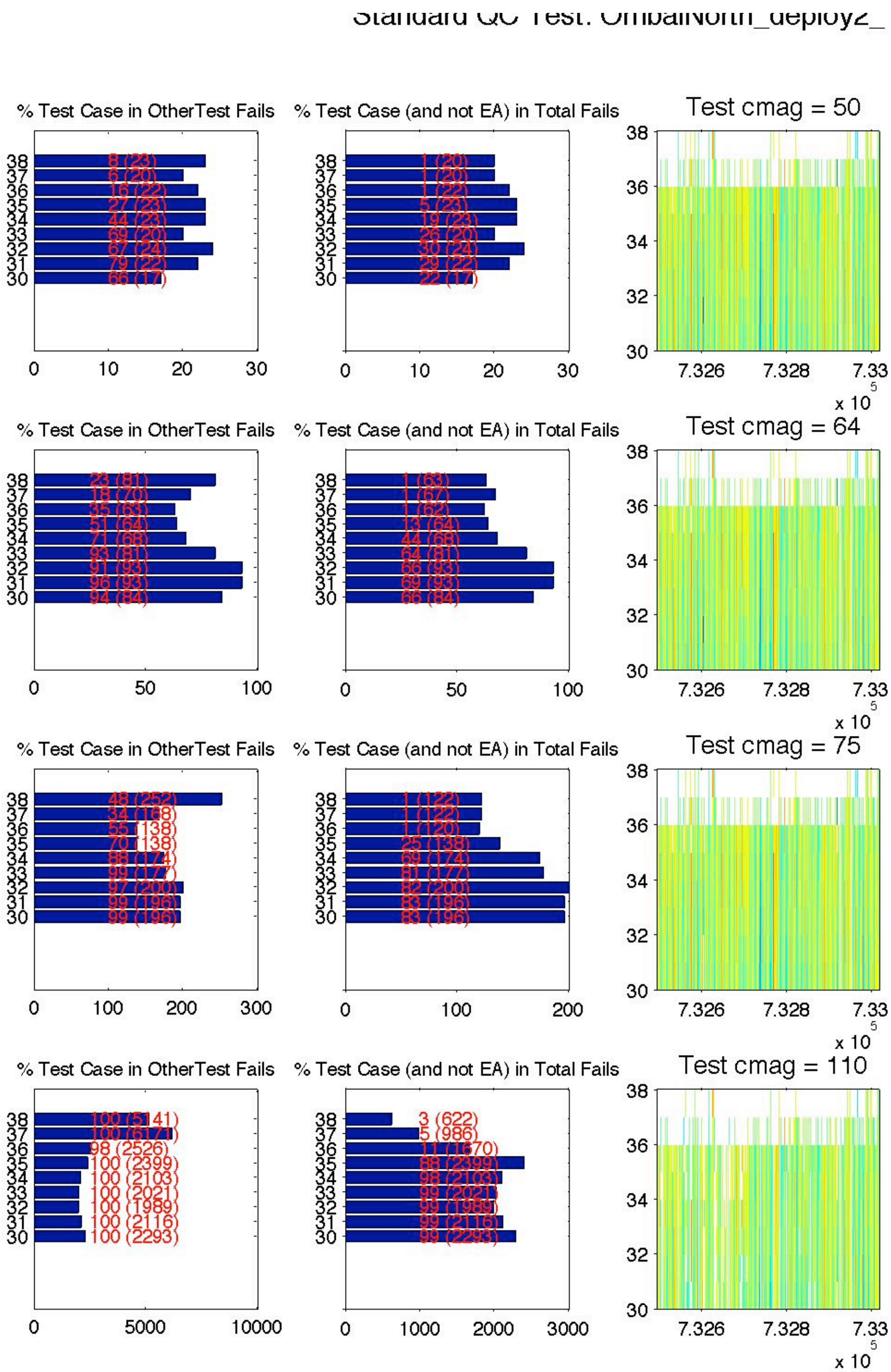

Figure 2c: Histograms of the contribution of the Correlation Magnitude (test 2) failures to the OTfails (left hand panels) and the contribution of these OTfails to the total fails (middle panels), where P(N) indicates the percentage (P) and number (N) of failures to the total number of failures in each bin and the resulting meridional velocity field (right hand panels) for threshold parameters of a) 50; b) 75; c) 110 and d) 150.

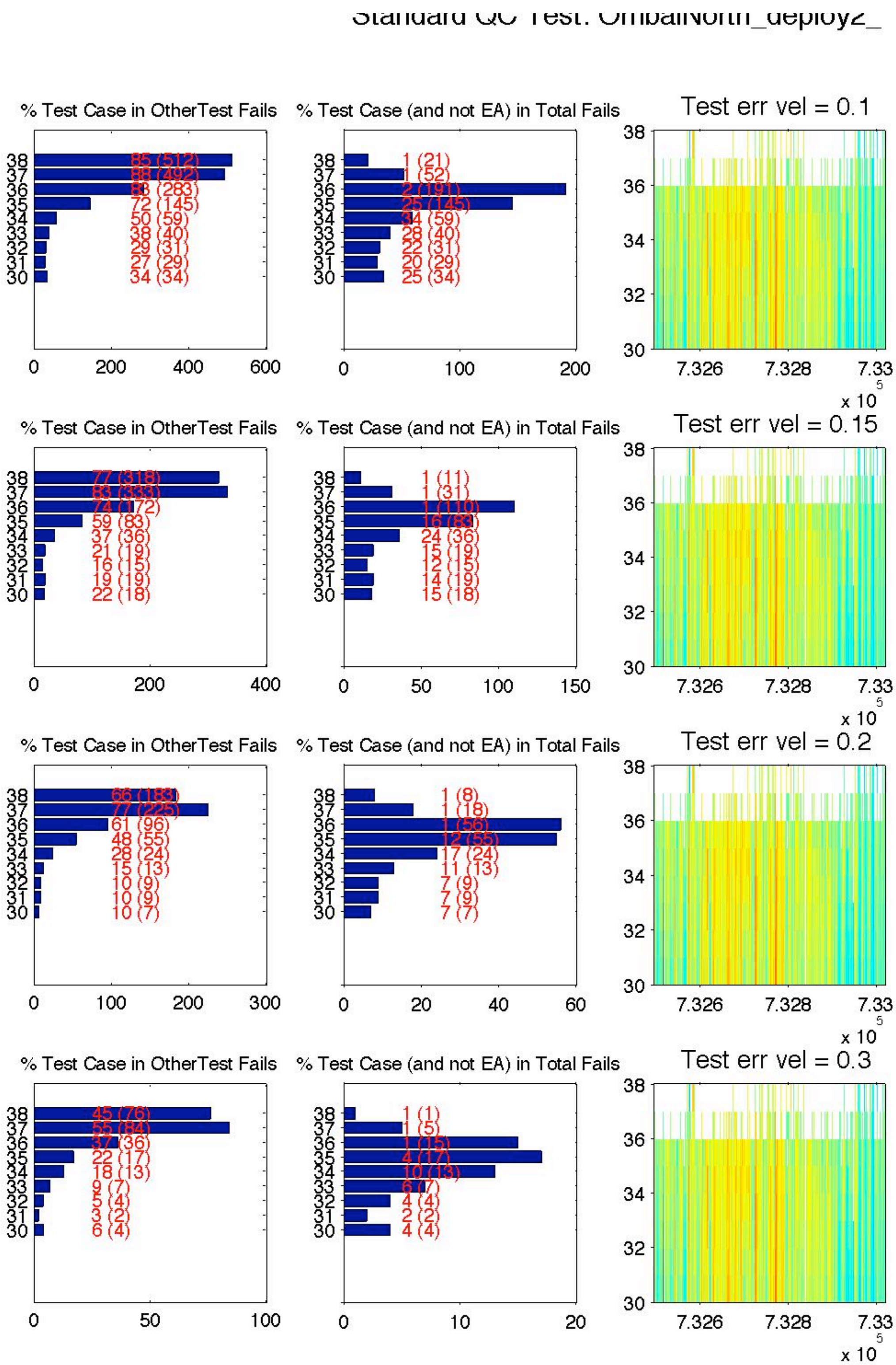

Figure 2d: Histograms of the contribution of the Error Velocity (test 3) failures to the OTfails (left hand panels) and the contribution of these OTfails to the total fails (middle panels), where P(N) indicates the percentage (P) and number (N) of failures to the total number of failures in each bin and the resulting meridional velocity field (right hand panels) for threshold parameters of a) 0.1; b) 0.15; c) 0.2 and d) 0.3.

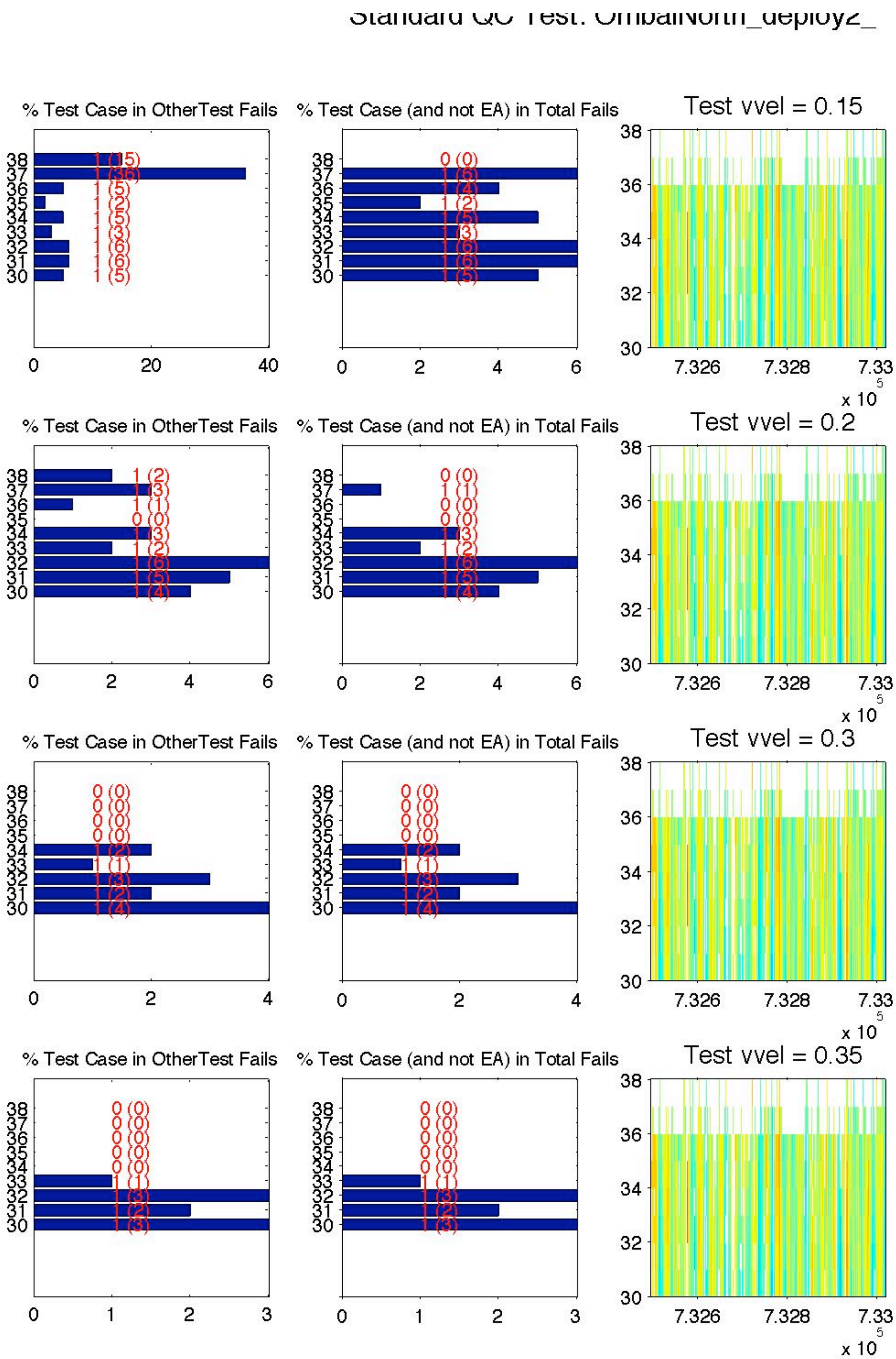

Figure 2e: Histograms of the contribution of the Vertical Velocity (test 4) failures to the OTfails (left hand panels) and the contribution of these OTfails to the total fails (middle panels), where P(N) indicates the percentage (P) and number (N) of failures to the total number of failures in each bin and the resulting meridional velocity field (right hand panels) for threshold parameters of a) 0.15; b) 0.20; c) 0.30 and d) 0.35 m/s.

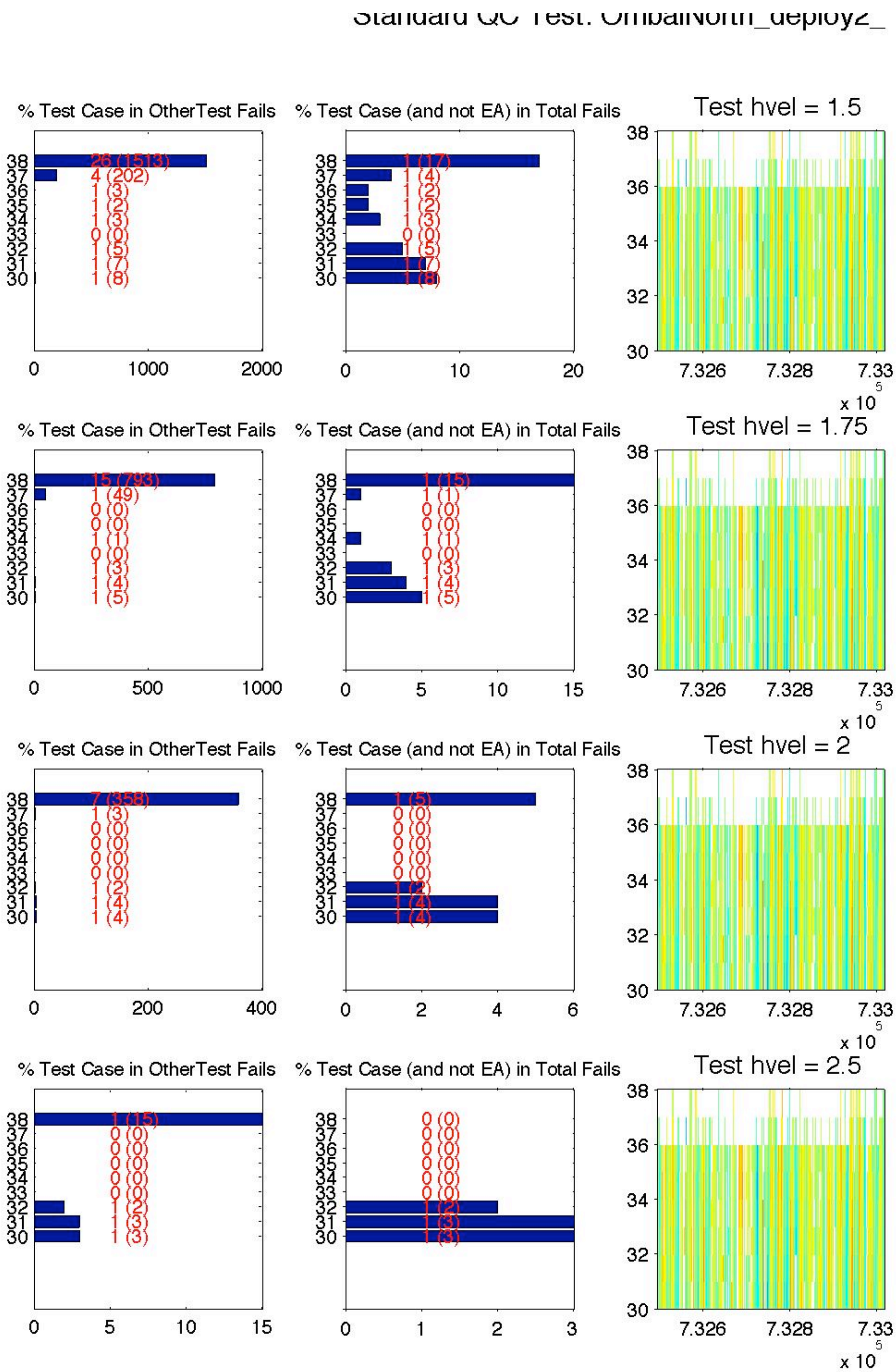

Figure 2f: Histograms of the contribution of the Horizontal Velocity (test 5) failures to the OTfails (left hand panels) and the contribution of these OTfails to the total fails (middle panels), where P(N) indicates the percentage (P) and number (N) of failures to the total number of failures in each bin and the resulting meridional velocity field (right hand panels) for threshold parameters of a) 1.5; b) 1.75; c) 2.0 and d) 2.5 m/s.