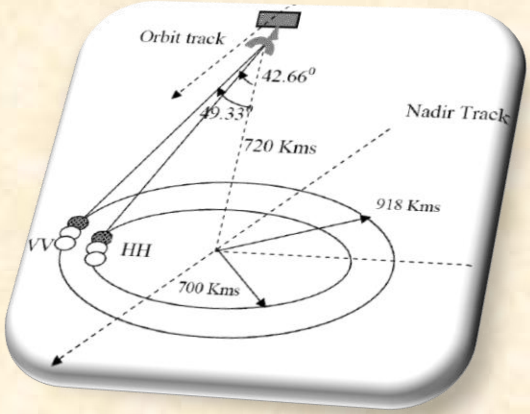
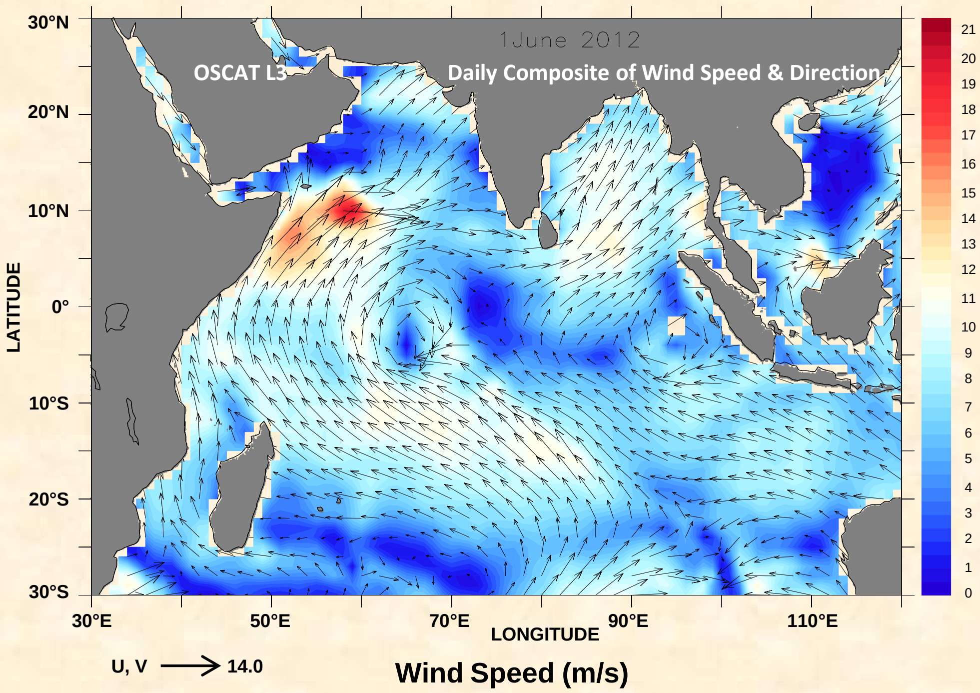
Generation of OSCAT Winds Daily Composites

Ver. 1.0



Oceansat-2 Scatterometer (OSCAT) Viewing Geometry



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Ocean Sciences Group
Earth and Climate Science Area
NATIONAL REMOTE SENSING CENTRE
INDIAN SPACE RESEARCH ORGANISATION
Hyderabad, INDIA

June 2013

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by

Chiranjivi Jayaram and A. Jeyaram

Regional Remote Sensing Centre-East, NRSC/ISRO, Kolkata

Debadatta Swain, Saurabh Bansal and K. H. Rao

National Remote Sensing Centre (NRSC), ISRO, Hyderabad

Udaya Bhaskar T. V. S. and E. Pattabhi Rama Rao

Indian National Centre for Ocean Information Services (INCOIS), Hyderabad

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9.	**Affiliation of authors**	[1]Regional Remote Sensing Centre-East, NRSC/ISRO, Kolkata [2]Indian National Centre for Ocean Information Services (INCOIS), Hyderabad [3]Ocean Sciences Group, National Remote Sensing Centre (NRSC), ISRO, Hyderabad			
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Abstract:
Daily composites of Oceansat-2 Scatterometer (OSCAT) L3 winds are generated using Data-Interpolating Variational Analysis (DIVA) method. The product is generated on an experimental basis for the year 2012 for the Indian Ocean region. The output daily composite winds from OSCAT are then validated using *in situ* buoys and Advanced Scatterometer (ASCAT) and QuikSCAT winds. OSCAT wind composites are observed to be matching well with both *in situ* (RAMA & NDBP buoys) and ASCAT and QuikSCAT winds. However, there exists minor deviations in the wind vectors in comparison with ASCAT, and these are attributed to the inherent differences in interpolating methodologies. ASCAT used ECMWF winds for temporal interpolation while for OSCAT, only scatterometer estimated winds are used. Further, this approach also makes OSCAT wind products more reliable.

Key Words: *OSCAT, DIVA, ASCAT, QuikSCAT, RAMA & NDBP Buoys, Indian Ocean*

Contents

Summary

Oceansat-2 scatterometer (OSCAT) is an active microwave sensor onboard the Oceansat-2 satellite launched by Indian Space Research Organisation (ISRO) on 23rd September 2009. It is a Ku-band pencil beam scatterometer operating at 13.515 GHz with a ground resolution cell size of 50 km x 50 km. OSCAT was intended to provide ocean surface wind vectors covering the global oceans with a revisit time of 2 days. In the present work, an attempt has been made to generate daily composites of OSCAT Level-3 (L3) wind vectors using Data-Interpolating Variational Analysis (DIVA) method. The product is generated on an experimental basis for the year 2012 for the Indian Ocean region. The output daily composite winds have been validated using Advanced Scatterometer (ASCAT) and winds from *in situ* buoys (RAMA and Indian NDBP) for the year 2012, as well as Quick Scatterometer (QuikSCAT) winds for a short overlap period. The generated products are observed to be in overall agreement with both *in situ* and ASCAT, QuikScat winds. However, minor deviations are seen to exist in the wind vectors when compared with ASCAT, and these could be attributed to the inherent differences in interpolating methodologies. ASCAT used European Centre for Medium-Range Weather Forecasts (ECMWF) winds for temporal interpolation while for OSCAT, only scatterometer winds are used and therefore deemed to be more reliable. The work shall be extended to 25 km x 25 km and 12.5 km x 12.5 km OSCAT L3 wind products once the data is available. Later, attempt shall also be made to obtain the composites from OSCAT L2 products directly.

1. Rationale

Oceansat-2 scatterometer (OSCAT) has been providing sea surface winds since September 2009. OSCAT is one of the 3 payloads on board the Oceansat-2 satellite. It is a Ku-band pencil beam scatterometer developed by Indian Space Research Organisation (ISRO) providing global observations of sea surface winds (*SAC*, 2005; *Gohil et al.*, 2007). In order to make use of this wind data for operational purposes, one has to have a composite product of merged ascending and descending passes rather than individual passes. To utilize the OSCAT data presently made available through Oceansat-2 portal of National Remote Sensing Centre (NRSC), separate analysis for ascending pass and descending pass is required, which is practically tedious as well as demands avoidable computation time and resources. Moreover, the present product provide winds in the form of speed and direction, while most of the oceanographic community requires winds in the form of Zonal (U) and Meridional (V) components for obtaining derived parameters like wind stress and wind stress curl for any type of analysis as well as forcing various models. In this context, OSCAT daily composite winds have been generated by combining daily ascending and descending passes from OSCAT Level-3 (L3) products on an experimental basis using Data-Interpolating Variational Analysis (DIVA) method (*Truopin et al.*, 2010). The said methodology has been compared with the traditional objective analysis techniques applicable for similar applications and was found to be superior (*Troupin et al.*, 2010; 2013). The product generated is further compared with other existing scatterometer products like Advanced Scatterometer (ASCAT) composite winds and *in situ* met-ocean winds from **R**esearch Moored **A**rray for African-Asian-Australian **M**onsoon **A**nalysis and Prediction (RAMA) and National Data Buoy Programme (NDBP) buoys apart from few days of QuikSCAT winds.

2. Data-Interpolating Variational Analysis (DIVA)

DIVA is a data analysis tool developed by GeoHydrodynamic and Environmental Research (GHER) under the SeaDataNet project of the European Union (*Troupin et al.*, 2010; *Udayabhaskar et al.*, 2012). DIVA has the unique provision in-built into it to identify the coastline and topography and has a numerical coast independent of the number of observations. Automatic outlier detection based on the comparison of the data residual and the standard deviation is some of the additional features of this analysis tool (*Troupin et al.*, 2010). It is therefore considered suitable for the present work. Daily ascending and descending passes of OSCAT are merged and a daily OSCAT wind product is generated using DIVA. Figure 1 presents the flow diagram of the procedure followed for generation of daily composites of OSCAT winds. DIVA utilizes Variational Inverse Method (VIM) for data interpolation (*Brasseur et al.*, 1996).

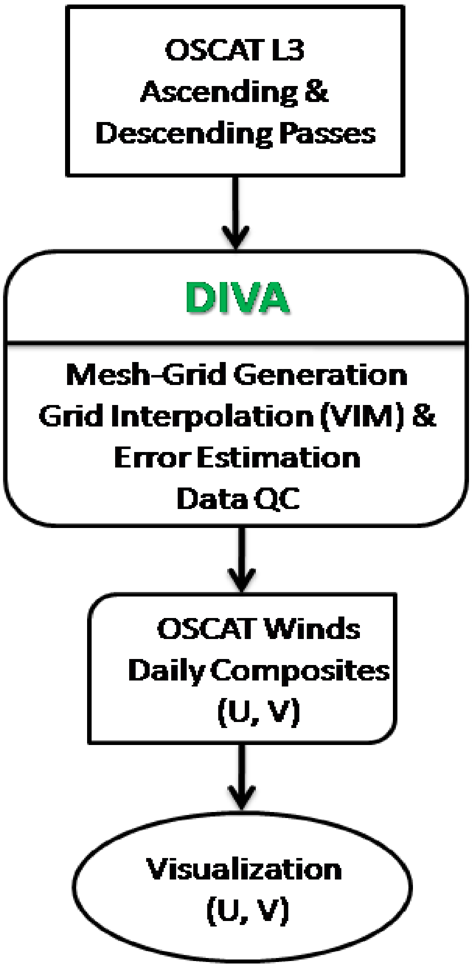

Figure 1: Flow diagram of DIVA processing for OSCAT Wind composites.

The above mentioned utility was run on a work station comprising of 2 CPU Six Core Intel® Xeon® 5600 series Processor 2.66 GHz, and 96 GB RAM. The processing time for generation of spatially interpolated OSCAT data took approximately 60 hours for a one month long data set for the Indian Ocean region (-30 to 30 °N and 30 to 120 °E) alone (~ 120 minutes per day at 0.5º resolution). It is expected that once the method is evaluated and the results are accepted, generation of daily output would be faster. An overview of the zonal winds for ascending, descending and simple overlaid ascending and descending passes for 1st January 2012 are presented in Figure 2. Figure 3 presents the DIVA generated wind composite along with the error component for the same day. The error component in the spatially interpolated output is given on a scale of 0 - 1, with good data considered to be the one with error less than or equal to 0.3 (*Troupin et al.*, 2013).

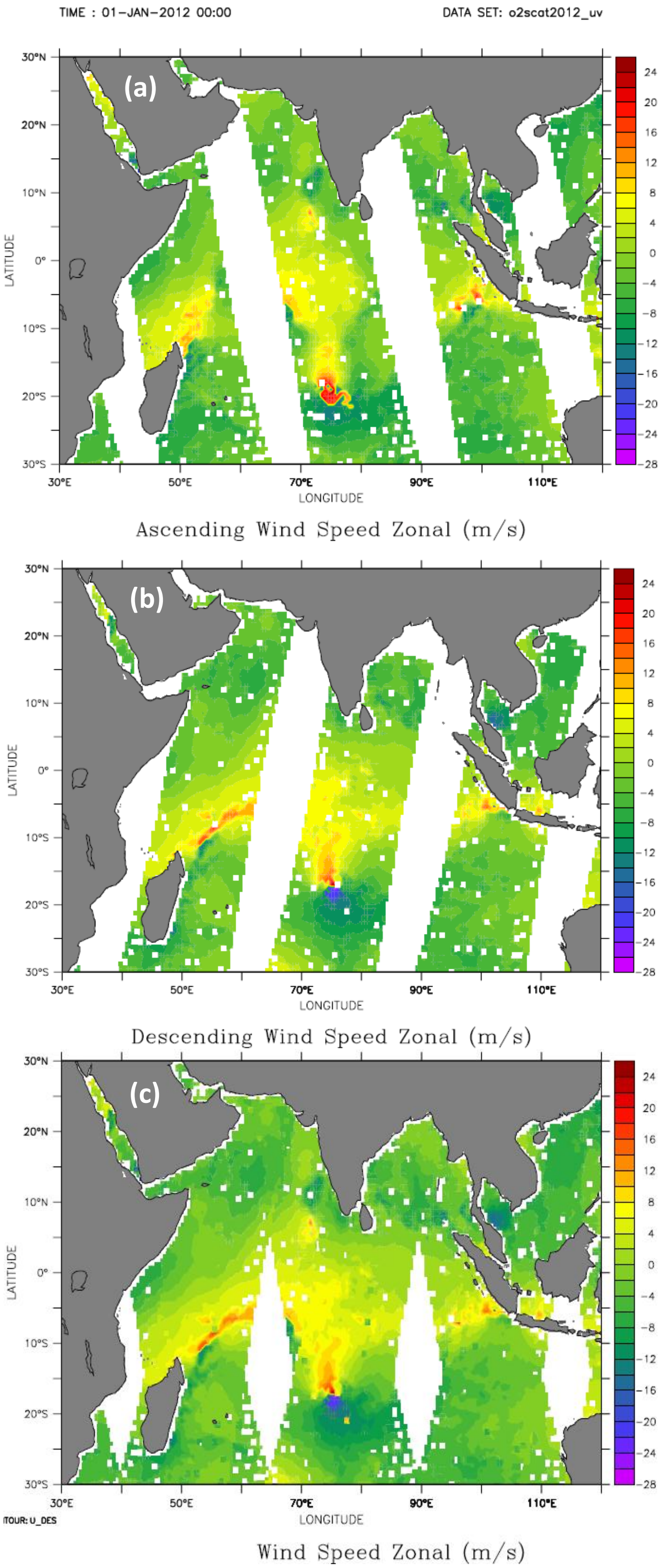

Figure 2: OSCAT L3 Zonal Winds for 1st Jan 2012: (a) Ascending Pass (b) Descending Passes (c) Simple overlaid Ascending and Descending Passes

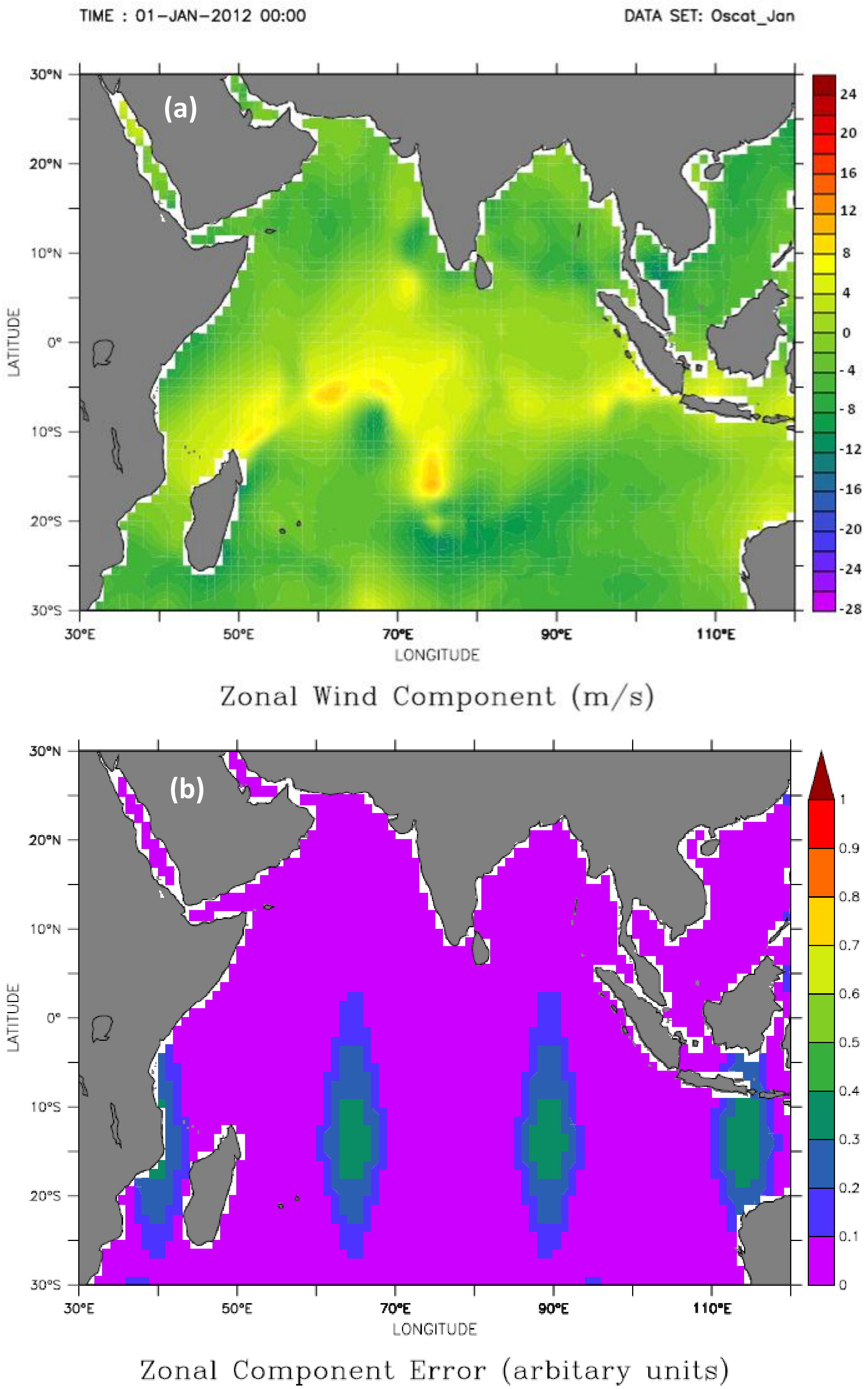

Figure 3: Generation of daily composite from OSCAT L3 Zonal Winds for 1st Jan 2012 using DIVA: (a) Daily composite (b) Computational Error

3. Analyses and Discussions

Following the development of methodology to generate daily composites of OSCAT winds, it is necessary to validate the generated products with other available wind products. Keeping this in view, first the original OSCAT winds have been compared with the Advanced Scatterometer (ASCAT) winds. ASCAT onboard Metop-A and B satellites provide daily estimations of sea surface winds at a resolution of 0.25° x 0.25°. ASCAT daily wind data is obtained from Live Access Server of INCOIS (las.incois.gov.in).

Following this, an intercomparison is also carried out between DIVA interpolated OSCAT daily wind composites and original OSCAT winds. To substantiate the results, an intercomparison is also carried out between DIVA generated OSCAT daily wind composites and standard available interpolated ASCAT winds for the same period. Further, validation of OSCAT actual winds and DIVA interpolated OSCAT daily wind composites have also been carried out in terms of comparison with QuikSCAT (*Hoffman and Leidner*, 2005) and *in situ* wind measurements by RAMA and NDBP buoys. The results are presented in the following subsections.

3.1. Inter-comparison between actual OSCAT and ASCAT winds

OSCAT L3 wind data used for the purpose is obtained from the Oceansat-2 data portal of NRSC. The spatial resolution of OSCAT winds used for the analysis is 50 km x 50 km. Further for the comparison, ASCAT 25 km x 25 km winds are up-scaled to 50 km x 50 km resolution by skipping the intermediate values on the grid.

For the present analysis, the winds for entire one year duration (2012) are considered. The Root Mean Square Deviation (RMSD) between un-interpolated OSCAT and ASCAT zonal and meridional winds for the entire one year period of 2012 is shown in Figure 4. From the figure, it is observed that on an average, relatively higher RMSD values show a larger spatial spread for the ascending pass than compared with the descending pass. Larger errors are observed for both the passes in the southern and equatorial Indian Ocean regions. The reasons for this need to be investigated further.

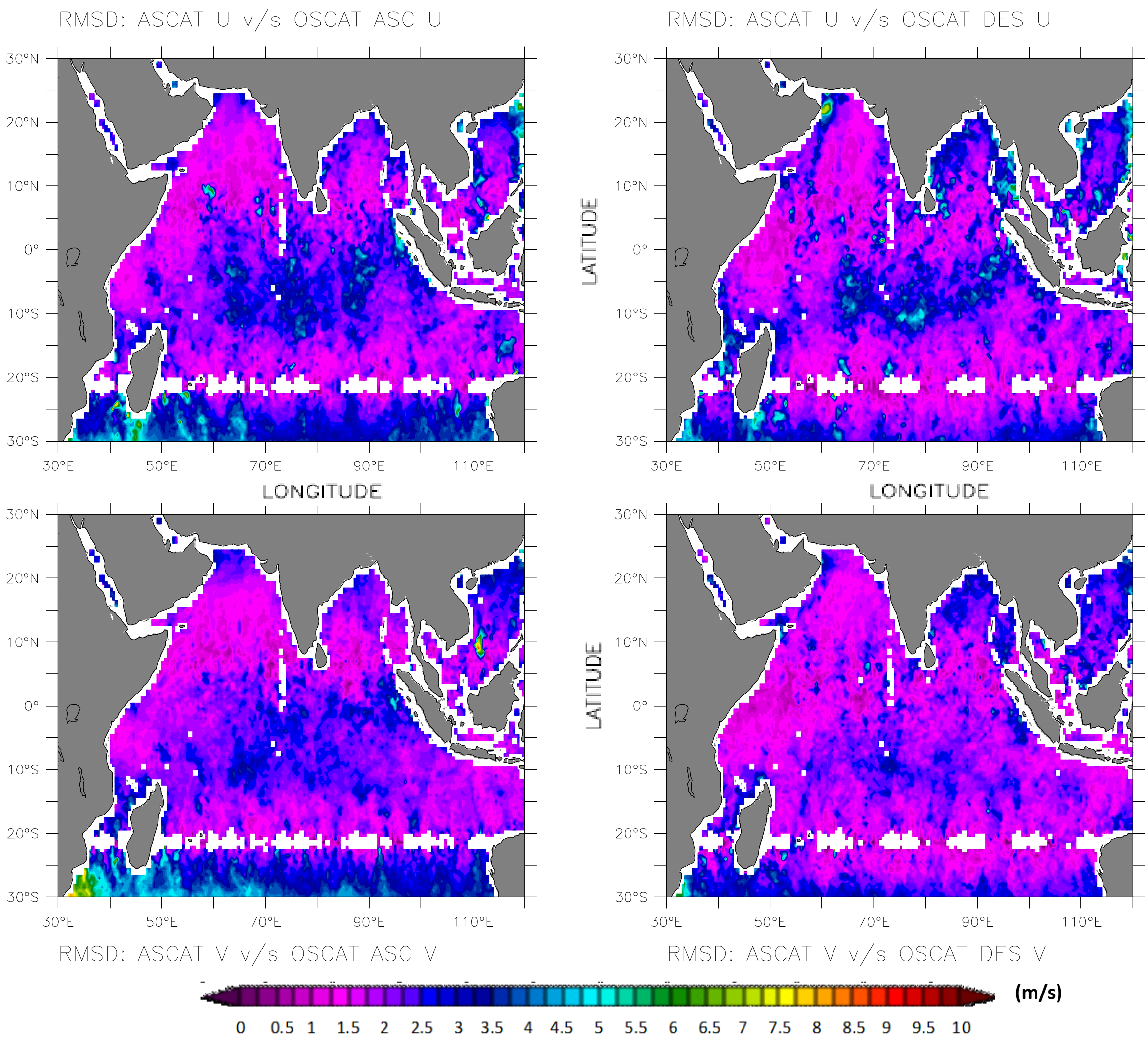

Figure 4: RMSD (m/s) between un-interpolated OSCAT and ASCAT winds during 2012. Left panel represents Ascending pass and right panel represents Descending pass

Figure 5 shows the correlation between un-interpolated OSCAT and ASCAT winds for both ascending and descending passes. The regions within the black contours are statistically insignificant regions and are quite few. From the figures, it can be inferred that OSCAT winds are well correlated with ASCAT winds even at 95% statistical significance in the two tailed student t-test analysis. Here too, descending pass is correlating better than the ascending pass as in case of RSMD and almost all of the tropical Indian Ocean falls under the 95% statistically significant region.

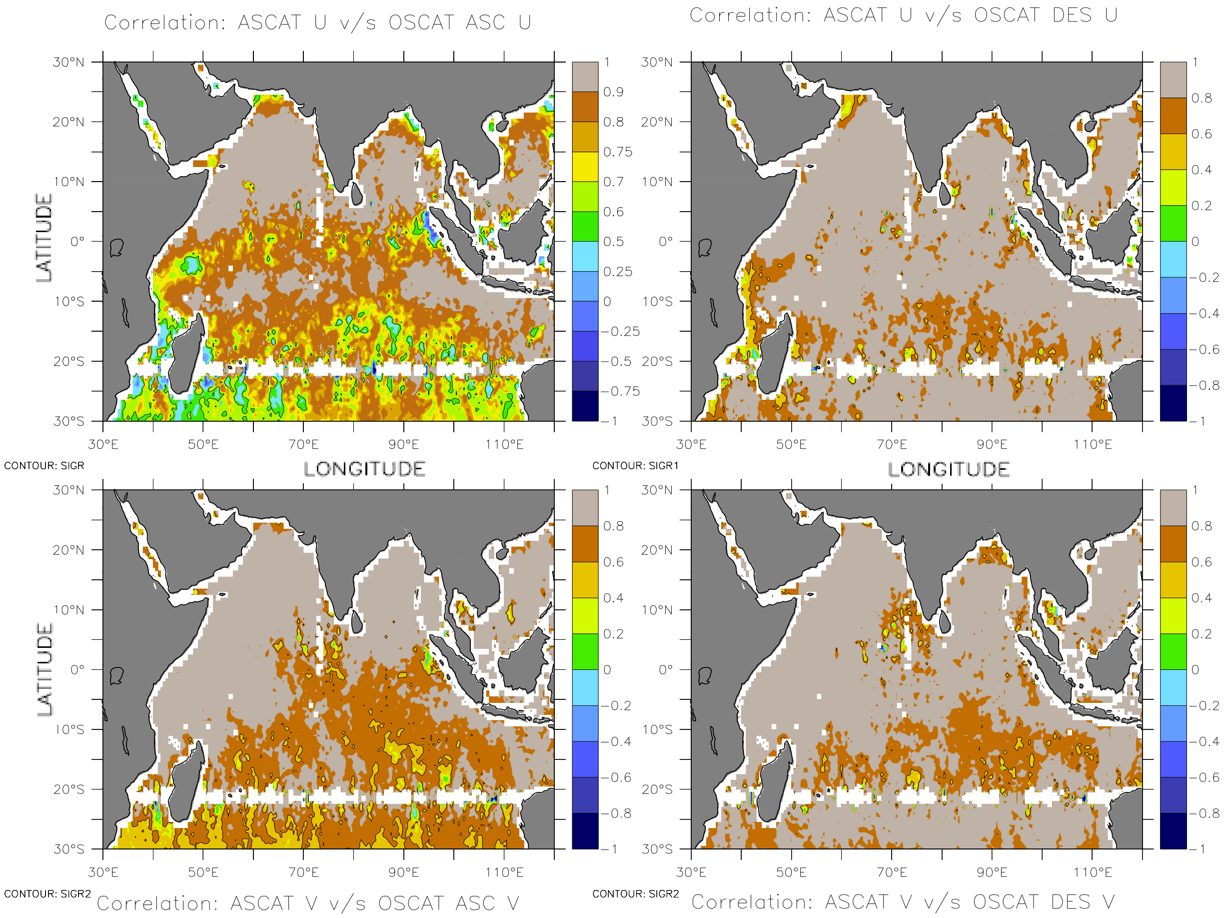

Figure 5: Correlation between OSCAT and ASCAT winds at 95% confidence level (except for area within black contours). Left panel represents Ascending pass and right panel represents Descending pass

3.2. Inter-comparison between DIVA interpolated and actual OSCAT winds

In order to evaluate the quality of the DIVA generated product, an exercise to compare the original wind vectors and the DIVA interpolated wind vectors of OSCAT was undertaken. Figure 6 shows a schematic of the interpolated DIVA output of OSCAT winds for 1st June, 2012. The wind vectors in the interpolated data show a prominent south-westerly direction which is inherent to the southwest monsoon prevailing during June thus, ably reproducing the feature.

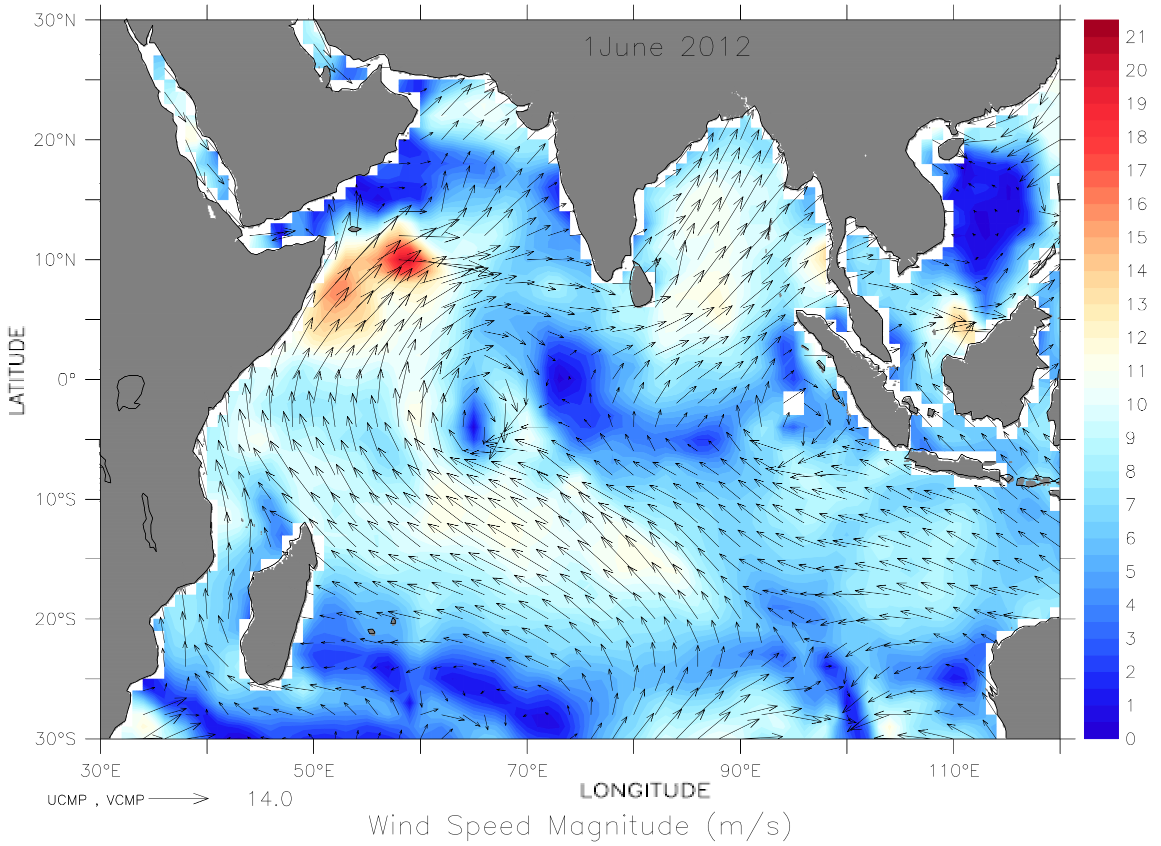

Figure 6: Wind Speed Magnitude (m/s) of OSCAT daily composite for the Indian Ocean region on 1st June 2012. Vectors indicate the direction of winds.

Figure 7 presents the comparison between the original wind vectors and DIVA interpolated wind vectors of OSCAT during some days in January 2012 as example. From the figure, it is observed that the cyclonic circulation in the southern Indian Ocean is picked up well in DIVA interpolated winds which do match with the original OSCAT wind vectors. It shows that the interpolated product is quite accurate with respect to the original product limited to minor variations in the vector angles seen at the swath edges.

Thus, the results from the comparison are quite encouraging with very good match between original OSCAT winds and DIVA interpolated winds in the regions where original OSCAT data is available, and with a slight shift in the regions where the winds are interpolated. Considering this and the results presented in Figure 3, the methodology adopted and the quality of the DIVA output for OSCAT are found to be promising.

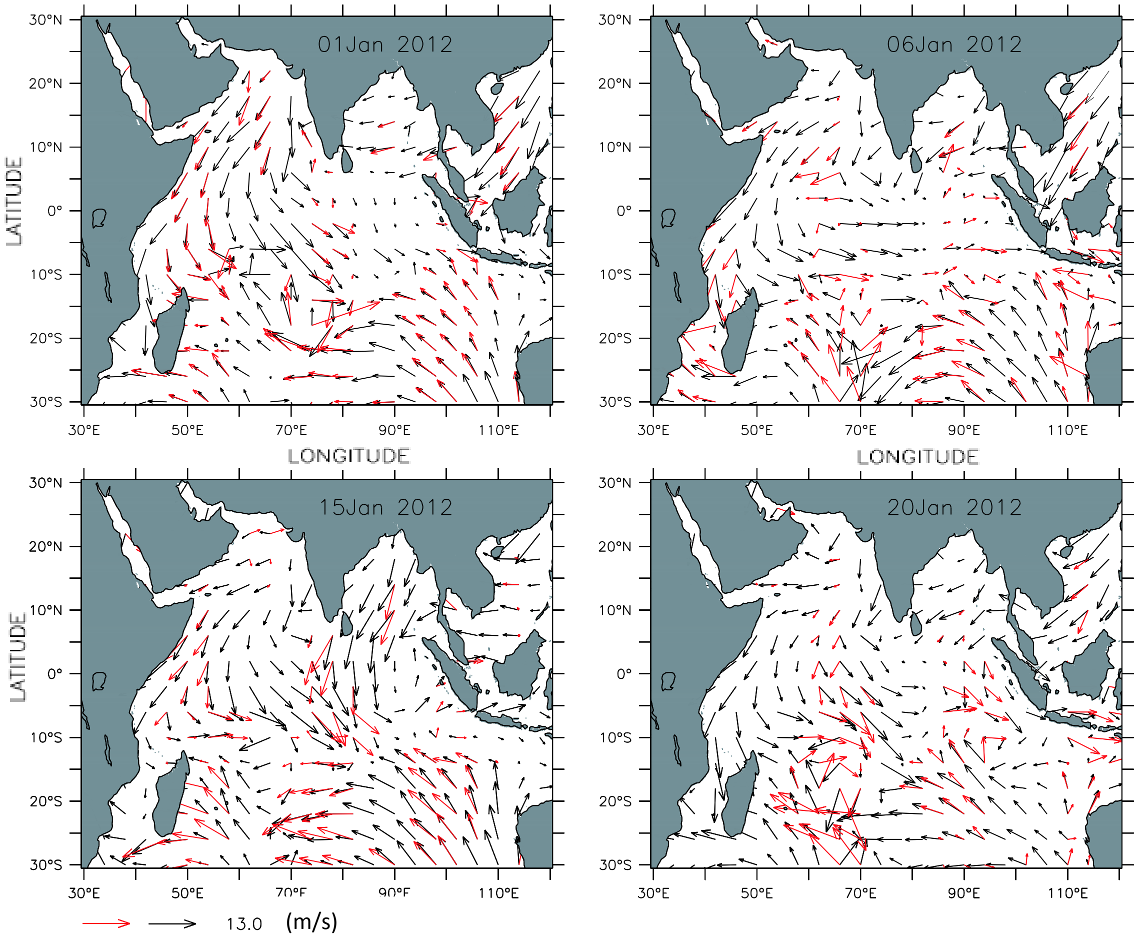

Figure 7: Schematic showing the DIVA interpolated daily composites of wind vectors and the original wind vectors from OSCAT on different dates during January 2012. Red Vectors represent the original wind vectors and **black vectors** represent the **DIVA generated** winds.

3.3. Inter-comparison between DIVA interpolated OSCAT and ASCAT winds

To further examine the accuracy, the DIVA interpolated OSCAT winds are compared with ASCAT wind vectors for the same period. In the generation of ASCAT daily wind composites, European Centre for Medium Range Weather Forecasting (ECMWF) model winds are used to fill the gaps between two passes through interpolation (*Bentamy and Fillon*, 2012). The figures in the subsequent sections elucidate the quality of DIVA generated OSCAT daily wind composites vis-a-vis ASCAT composite winds which are found to be matching well.

The RMSD and correlations between DIVA interpolated OSCAT winds and ASCAT standard interpolated winds during the entire one year period of 2012 are shown in Figure 8 for the zonal and meridional wind components. As can be seen there is good match between the two at 95% confidence level. The RMSD is less than 2 m/s in most parts of the Indian Ocean except in the extreme south-western part (particularly in meridional winds). However, it may be noted that this region does not fall in the 95% confidence level.

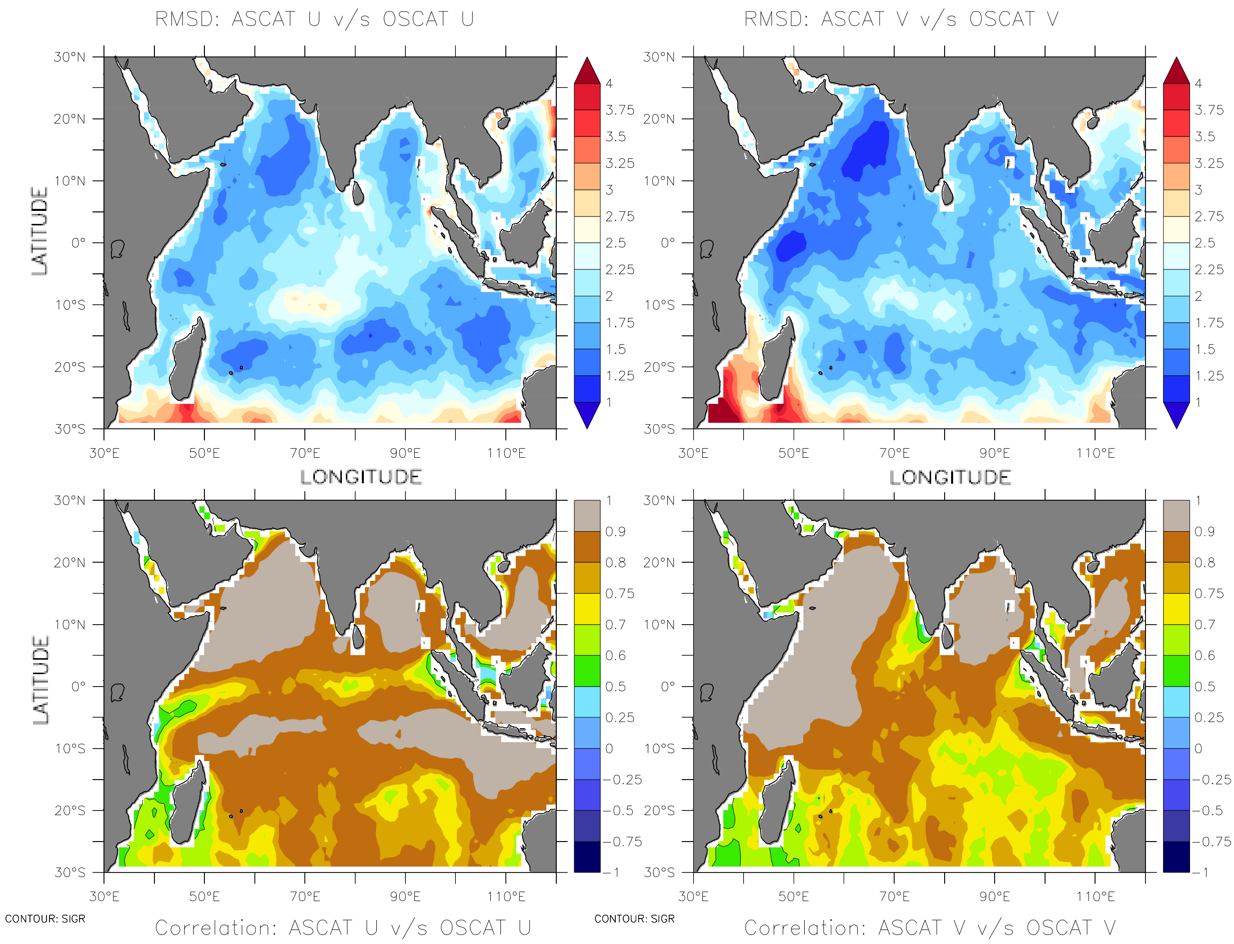

Figure 8: RMSD (m/s: Upper panel) and Correlation (Lower panel) between DIVA generated OSCAT composite winds and ASCAT winds at 95% confidence level (except for area within black contours) during 2012. Left panel represents Zonal winds and right panel represents Meridional winds.

Figure 9 presents a comparison of DIVA interpolated daily composite of OSCAT wind vectors and standard ASCAT interpolated wind vectors for month's representative of different seasons during 2012. The match between the wind vectors from ASCAT and OSCAT is relatively good. Slight mismatches at some regions observed are due to the fact that ASCAT daily winds make use of ECMWF winds to interpolate between successive passes on a given day while OSCAT wind composites generated through DIVA are a result of purely scatterometer wind estimations and no smoothing is involved. This makes the DIVA generated OSCAT wind composites even more reliable.

In order to smoothen out the deviations, an experiment can be undertaken involving a 2-day moving average given the fact that the repetitivity of OSCAT is 2 days. Therefore, gaps that may exist in a daily composite can be easily filled and a comprehensive product can be generated considering a 2-day moving average. Efforts in this direction are already underway and the comparison results will be brought out soon.

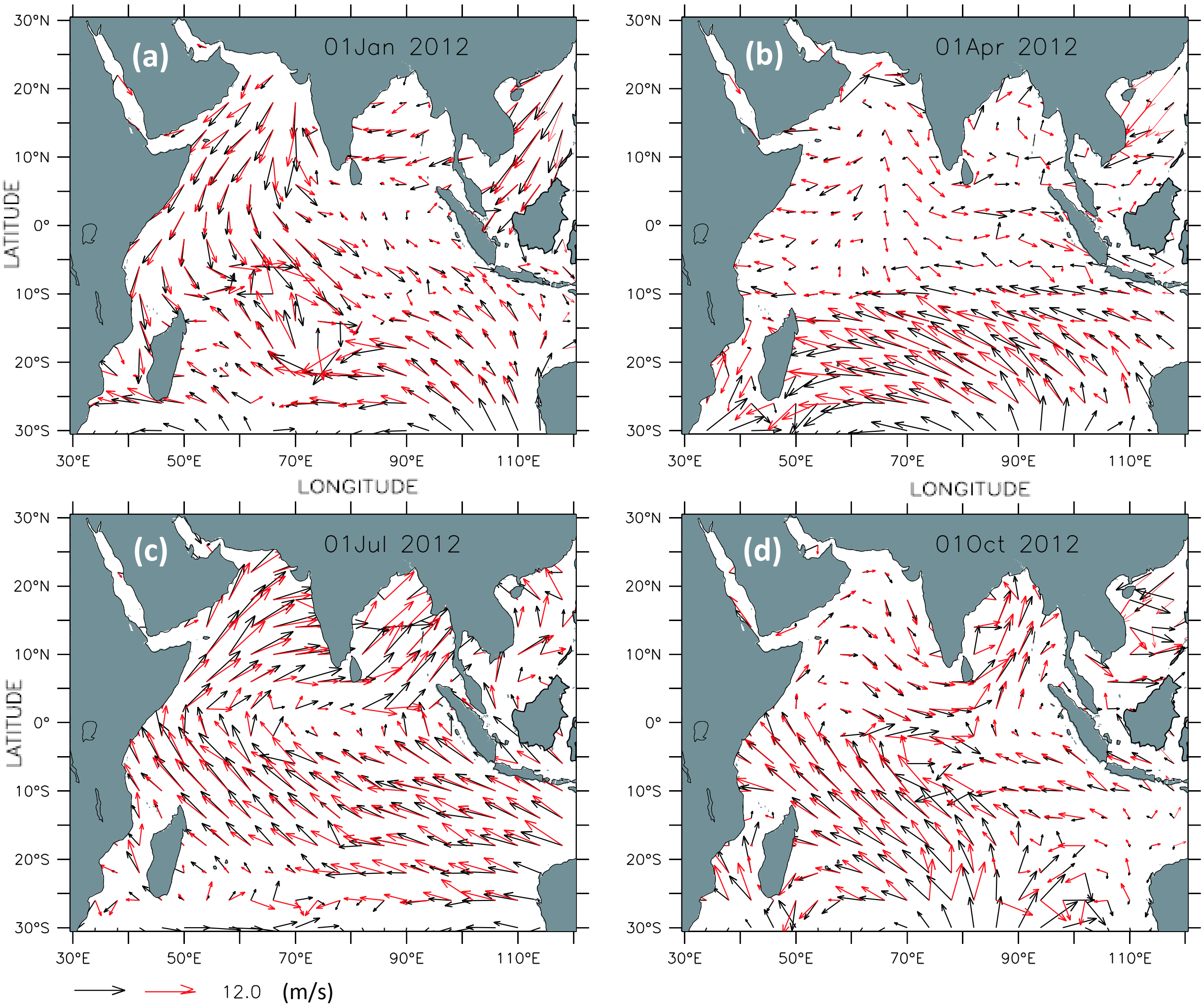

Figure 9: Comparison of daily composites of Wind Vectors from ASCAT and DIVA generated OSCAT for sample days during 2012 for months representing the four seasons: (a) 1st January for Winter Monsoon, (b) 1st April for Pre-Summer Monsoon, (c) 1st July for Summer Monsoon & (d) 1st October for Post-Summer Monsoon. Red vectors represent ASCAT and **Black** vectors for DIVA generated **OSCAT composites**.

Further qualitative comparisons were also carried out between OSCAT and QuikSCAT winds for some common days of overlap during the year 2009. The results for 1-day and 3-day simple composites of OSCAT and QuikSCAT winds are presented in Annexure – A.

3.4. Comparison with *in situ* observations

Before embarking on the exercise of generating a comprehensive daily wind composite, OSCAT winds have also been compared with winds measured by RAMA buoys. After obtaining confidence on the quality of the data, the above mentioned DIVA method was employed. RAMA buoys constitute a moored buoy array in the historically data-sparse Indian

Ocean that have provided very useful met-ocean measurements which have been successfully applied to advance monsoon research and forecasting (*McPhaden et al.*, 2009). The locations of RAMA buoys that were considered for comparison between winds from RAMA buoys and OSCAT are provided in Figure 1 under Annexure - B. RAMA buoy winds are measured at a height of 4 m from the surface while the scatterometer winds are at height of 10 m from the sea surface. In order to bring out meaningful validation, RAMA buoy winds are extrapolated to 10 m using power law as described in *Goswami and Rajagopal* (2003) and *Panofsky and Dutton* (1984).The comparison is then carried out for each of the parameters like ascending wind speed and direction, descending wind speed and direction and also the derived zonal and meridional components for the individual passes. Detailed figures illustrating the results are included in Annexure - B. Annexure – C also presents a comparison of DIVA generated OSCAT daily wind composites with wind measurements from NDBP of India & RAMA buoys during the year 2012. Measurements from NDBP buoys, AD2 and AD5, two of the several moored met-ocean buoys deployed by the National Institute of Ocean Technology (NIOT) under the NDBP for the Indian seas have been utilized for comparisons in the Arabian Sea (*Premkumar et al.*, 2000). The buoys provide various met-ocean parameters of which winds at a height of 3 m are used for comparison. The statistics of the comparisons are also provided in Tables 1 and 2 under Annexure – C. Derived parameters like wind stress and wind stress curl have also been obtained from DIVA interpolated OSCAT winds daily composite at 0.5° and 0.25° resolutions and sample figures for one day have been presented in Annexure – D.

4. Conclusions

Measurement of sea surface winds is vital for many operational purposes of which foremost are the studies relating to monsoons, General Circulation Models (GCMs) and cyclones. In order to undertake these studies, one needs to have quality wind data. Given the spatial and temporal constraints involved in *in situ* data, satellite based wind measurements have become a vital input for met-ocean studies. Towards achieving this with respect to the Indian scatterometer OSCAT, a methodology has been developed for generating daily composites of OSCAT winds and subsequently 2-day, weekly and monthly composites. DIVA is employed to generate OSCAT winds daily composites for the year 2012 in the Indian Ocean region on an experimental basis. Daily wind composites data are generated by merging both the ascending and descending passes of the corresponding calendar day. The wind products thus generated are validated with an existing operational scatterometer ASCAT and also *in situ* measured winds from RAMA and NDBP buoys in the Indian Ocean region. The results are found to be encouraging and matching well with other available scatterometers and *in situ* buoys' measurements. The deviations that are observed in the vector direction between ASCAT and OSCAT can be attributed to the utilization of ECMWF winds to interpolate and fill the gaps in case of ASCAT data. Additionally, qualitative comparisons are also carried between OSCAT winds and QuikSCAT winds. Once operational, the methodology will bring out winds and other derived products with many application potentials.

5. Future Works

In the present work, daily wind composites at 0.5° x 0.5° resolution from OSCAT have been generated for one year period of 2012 over the Indian Ocean region only. It has been restricted to the Indian Ocean region mainly due to the limitation in terms of computational time (Section 2). So, it is proposed to extend the generation of OSCAT daily wind composites to the global oceans as well as for all the available L3 OSCAT winds (all the years since 2009). The entire module shall be fully automated to operationally generate wind composites on a daily basis.

The work shall also be extended to 25 km x 25 km (to be released by ISRO shortly) and 12.5 km x 12.5 km OSCAT wind products once the data is available. Attempt would also be made to obtain the composites from OSCAT L2 data directly. The DIVA generated daily composite winds shall be made available as data in standard format and visulaization maps. It is also proposed to provide derivative products of wind stress, wind stress curl and other such parameters from the daily composites in lines of examples presented in Annexure – D.

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References

Bentamy A. and D. C. Fillon, 2012: Gridded surface wind fields from Metop/ASCAT measurements. *International Journal of Remote Sensing*, 33, 1729 – 1754.

Brasseur, P., J.-M. Beckers, J.-M. Brankert and R. Schoenauen, 1996: Seasonal temperature and salinity fields in the Mediterranean Sea: Climatological analyses of historical dataset. *Deep Sea Research - I*, 43, 159 – 192.

Gohil, B. S., K. Satheesan and A. K. Varma, 2007: Algorithm Theoretical Basis Document (ATBD): Wind vector retrieval algorithms for Oceansat-2 Scatterometer. *OCEANSAT-II-UP/SCATT-1/SAC-2007*, 38pp.

Goswami B. N. and E. N. Rajagopal, 2003: Indian Ocean surface winds from NCMRWF analysis as compared to QuikScat and moored buoy. *Proc. Indian Acad. Sci. (Earth & Planetary Science*), 112 (1), 61-77.

Hoffman, R. N. and S. M. Leidner, 2005: An Introduction to the Near–Real–Time QuikSCAT Data. *Weather Forecasting*, 20, 476 – 493.

McPhaden, M. J., G. Meyers, K. Ando, Y. Masumoto, V. S. N. Murty, M. Ravichandran, F. Syamsudin, J. Vialard, L. Yu and W. Yu, 2009: RAMA: The Research Moored Array for African–Asian–Australian Monsoon Analysis and Prediction. *Bulletin of the American Meteorological Society*, 90 (4), 459 – 480.

Panofsky H. A. and J. A. Dutton, 1984: Atmospheric Turbulence. *John Wily and Sons*, New York, 397pp.

Premkumar, K., M. Ravichandran, S. R. Kalsi, D. Sengupta and S. Gadgil, 2000: First results from a new observational system over the Indian seas. *Current Science*, 78 (3), 323 – 330.

SAC Report, 2005: Oceansat-II scatterometer payload. *Preliminary Design Review Document*, SAC/SCATT/PDR/01.

Troupin C., F. Machin, M. Ouberdous, D. Sirjacobs, A. Barth and J. M. Beckers, 2010: High resolution climatology of the northeast Atlantic using Data Interpolating Variational Analysis (DIVA). *Journal of Geophysical Research*, 115, C08005. doi:10.1029/2009JC005512.

Troupin, C., M. Ouberdous, D. Sirjacobs, A. Alvera-Azcárate, A. Barth, M.-E. Toussaint and J.-M. Beckers, 2013: DIVA User Guide. GeoHydrodynamics and Environment Research, Department of Astrophysics, Geophysics, University of Liège, Belgium, 199pp (http://modb.oce.ulg.ac.be/mediawiki/upload/DIVA/notes/DivaUserGuide_March2013.pdf).

Udaya Bhaskar T. V. S., C. Jayaram and E. P. Rama Rao, 2012: Comparison between Argo derived Sea Surface Temperature and Microwave sea surface temperature in the tropical Indian Ocean. *Remote Sensing Letters*, doi: 10.1080/2150704X.2012.711955.

ANNEXURE – A

Comparisons between QuikSCAT and OSCAT Sea Surface Winds

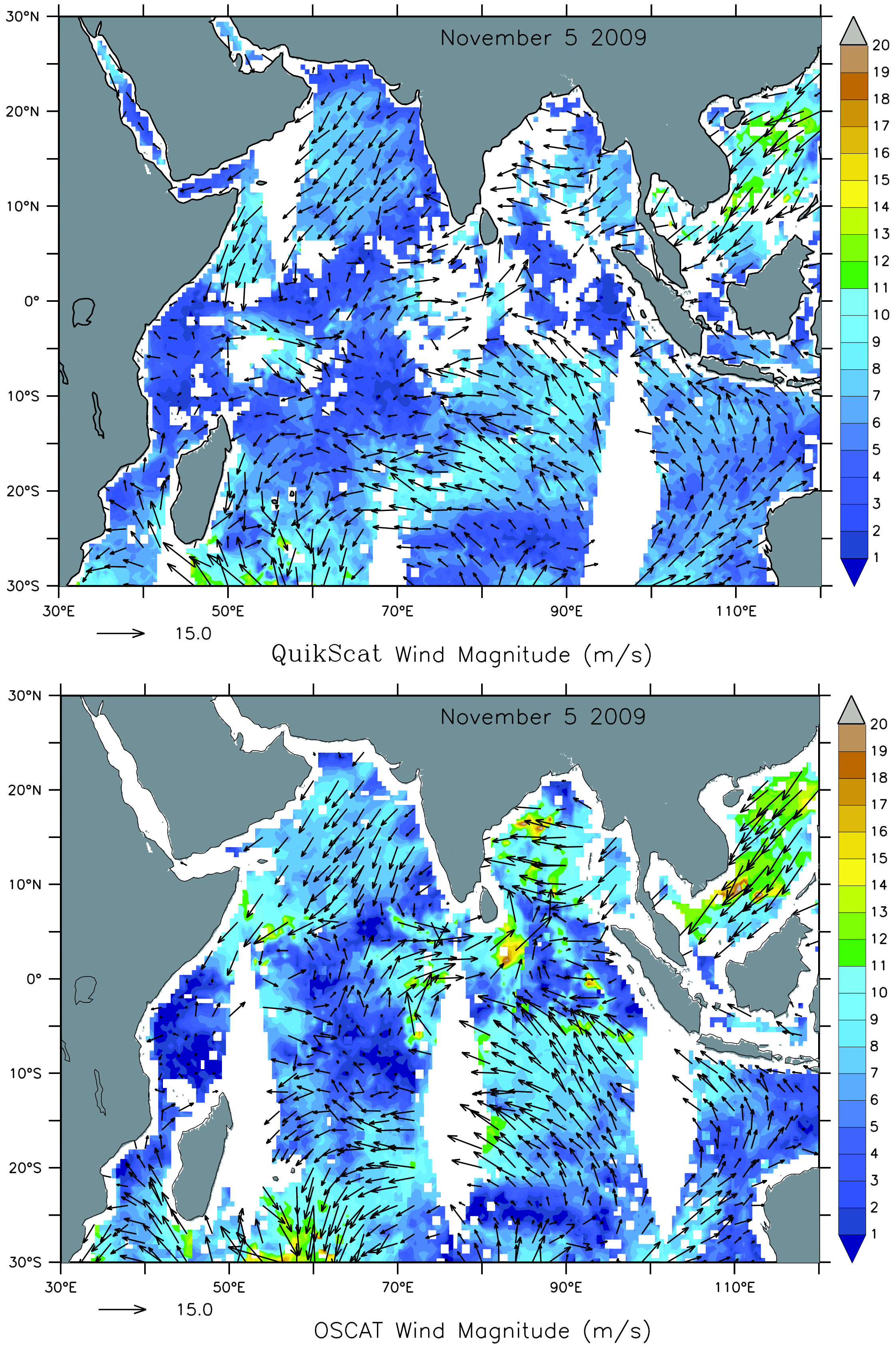

Figure 1: Qualitative comparison between QuikSCAT and OSCAT 1-day un-interpolated composite winds on 5th November 2009

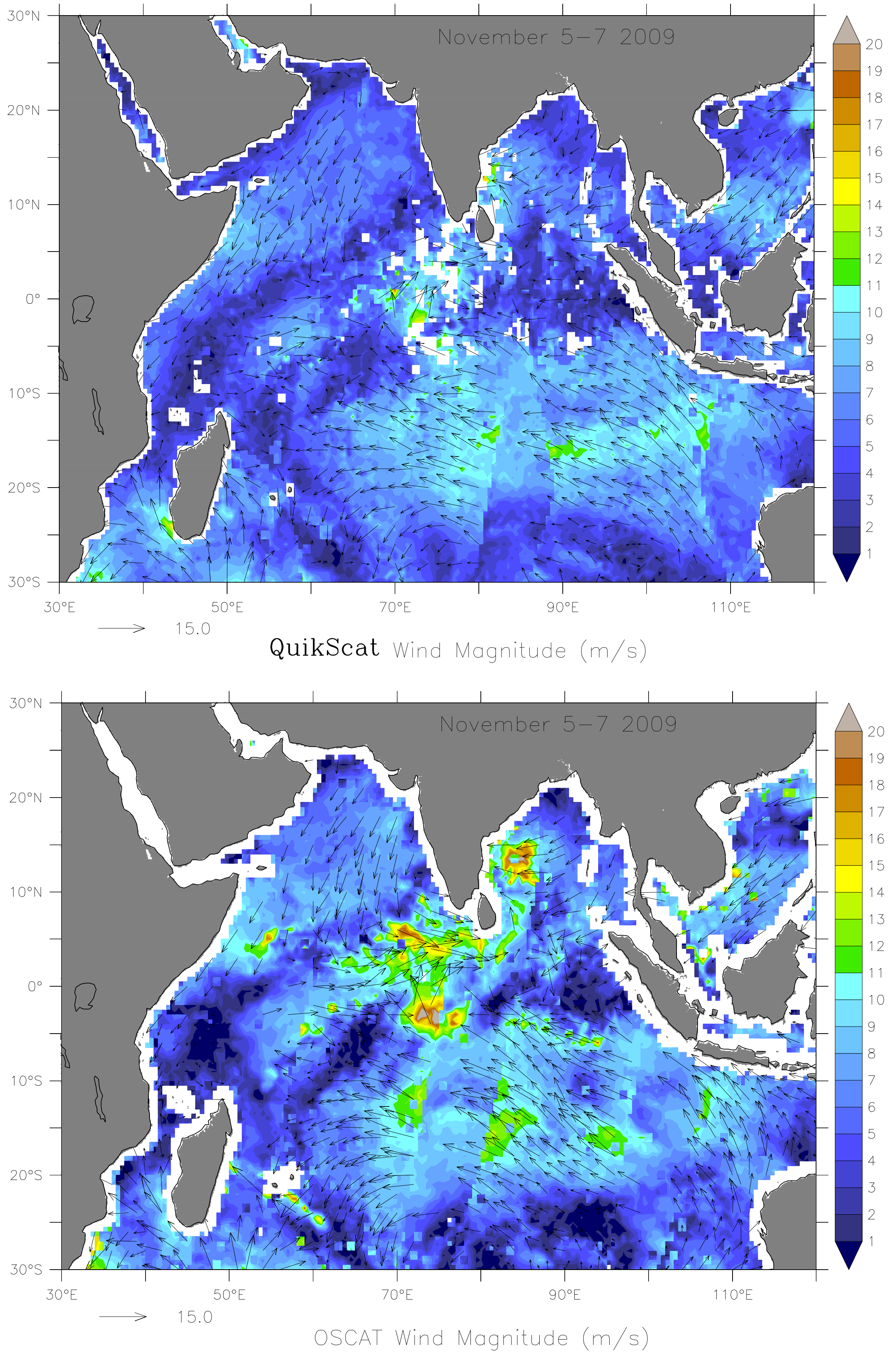

Figure 2: Qualitative comparison between QuikSCAT and OSCAT 3-day un-interpolated composite winds from 7th to 9th November 2009

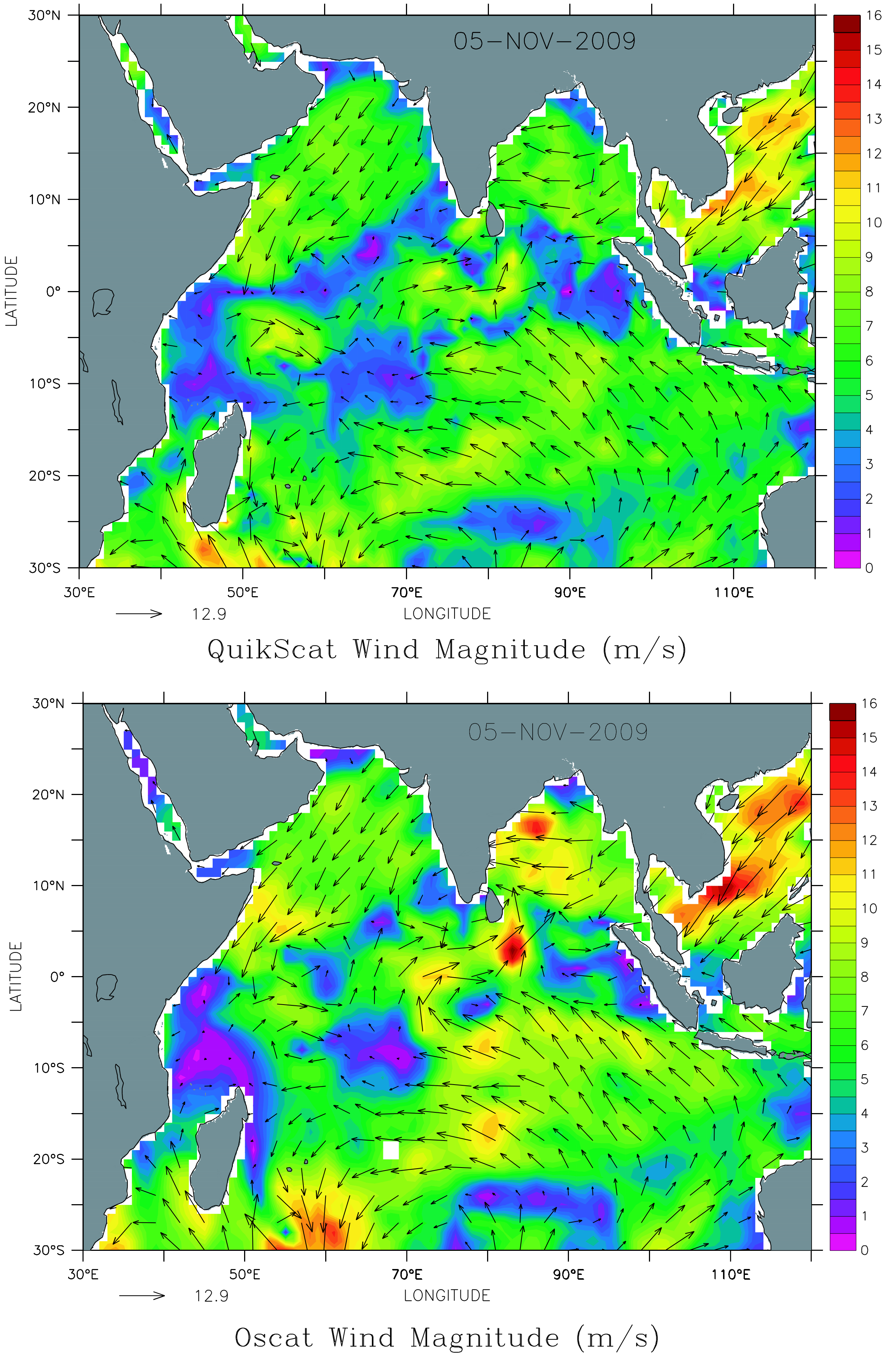

Figure 3: Qualitative comparison between DIVA generated QuikSCAT and OSCAT 1-day composite winds on 5th November 2009

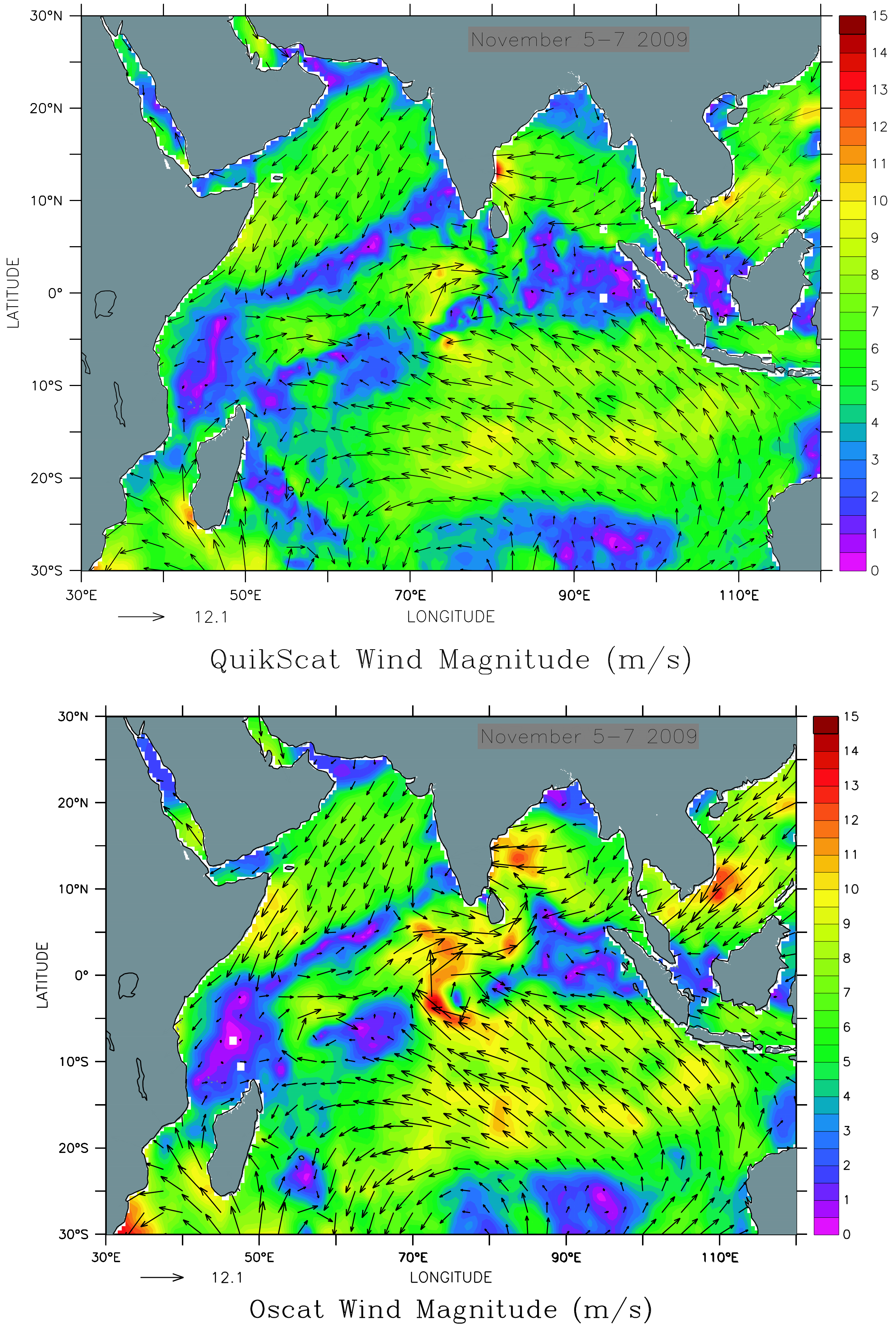

Figure 4: Qualitative comparison between DIVA generated QuikSCAT and OSCAT 3-day composite winds from 5th to 7th November 2009

ANNEXURE – B

Scatter plots and the corresponding statistics of comparison between actual OSCAT winds with winds measured by buoys at different RAMA locations

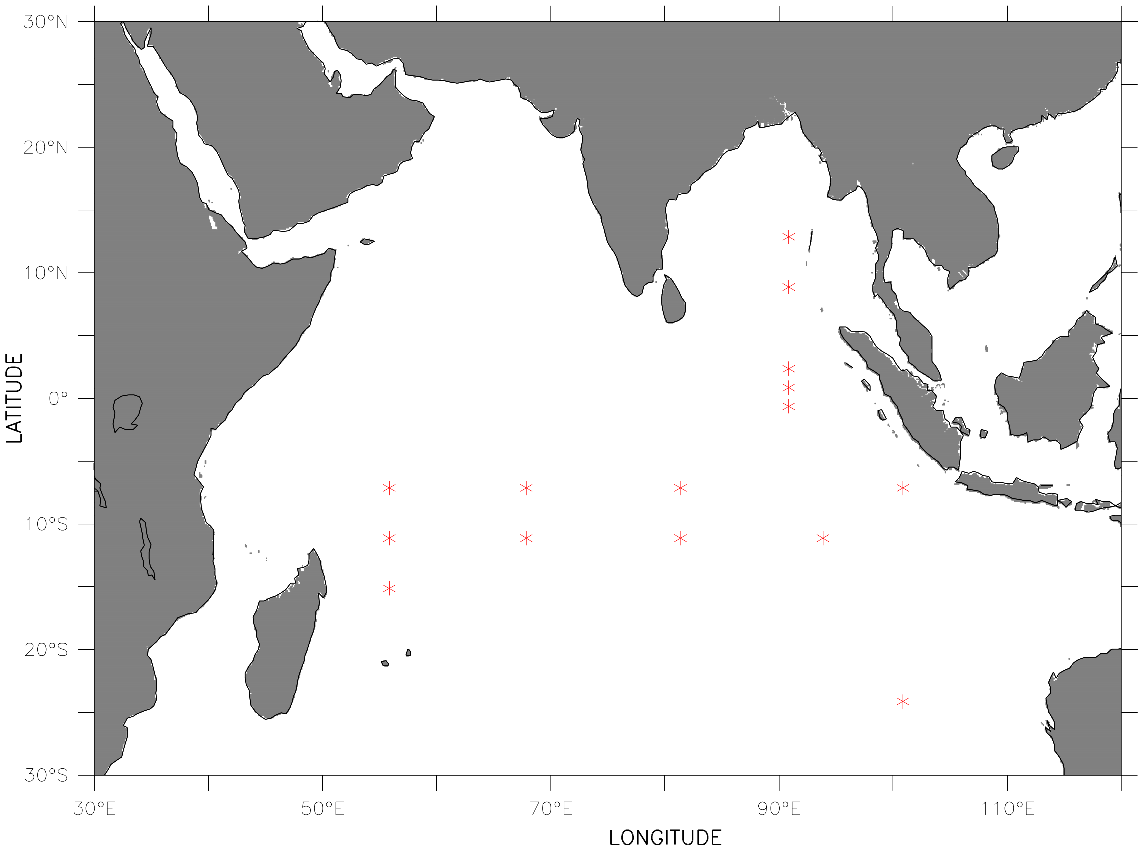

Figure 1: RAMA Buoy locations considered for comparison

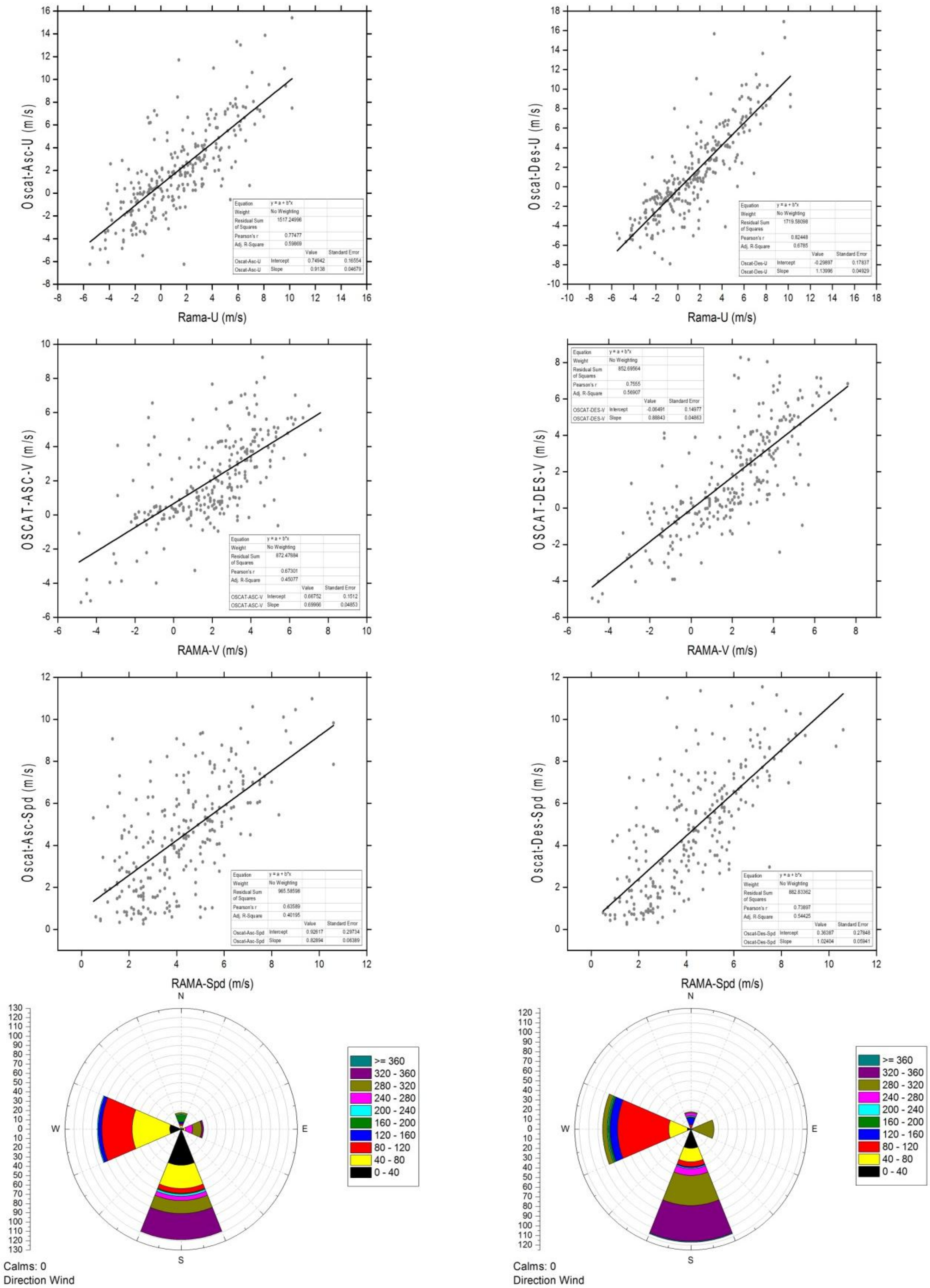

Figure 2: Comparison of un-interpolated OSCAT and RAMA buoy winds: U, V, Magnitude and Direction at the buoy location 0°, 90° E. Left panel represents Ascending Pass and right panel presents Descending pass.

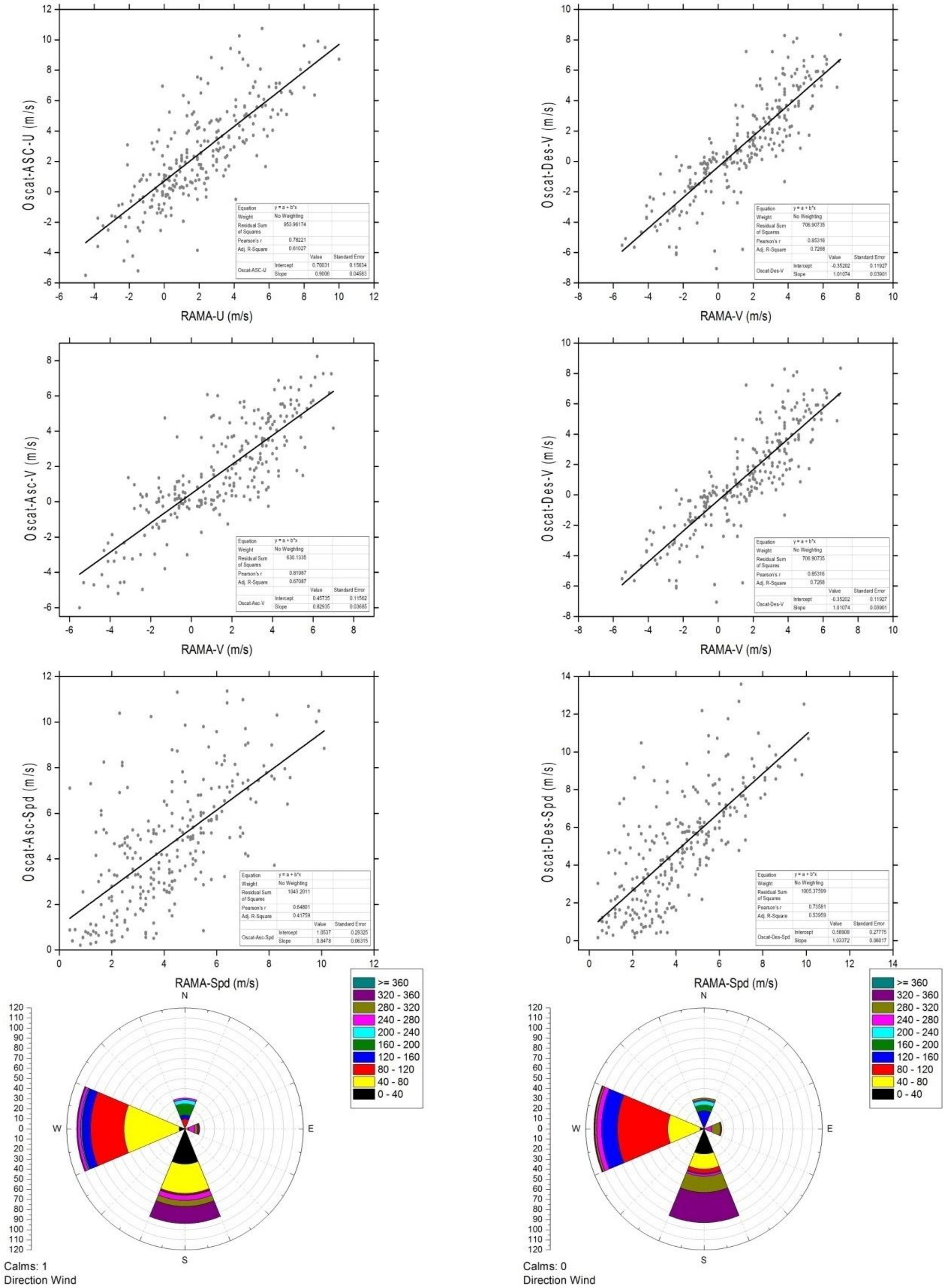

Figure 3: Same as Figure 2, but for buoy location: 1.5° N, 90° E

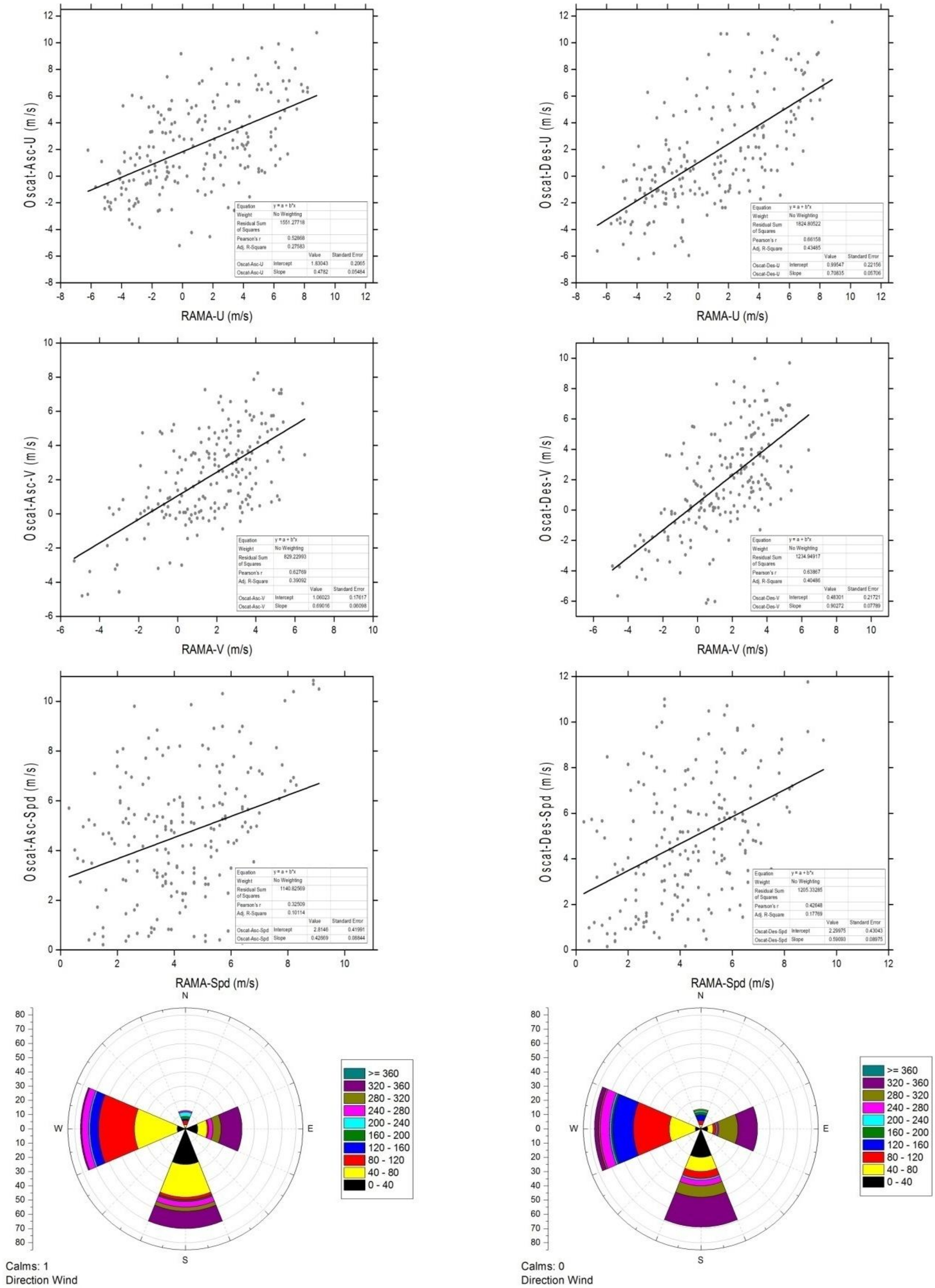

Figure 4: Same as Figure 2, but for buoy location: 1.5° S, 90° E

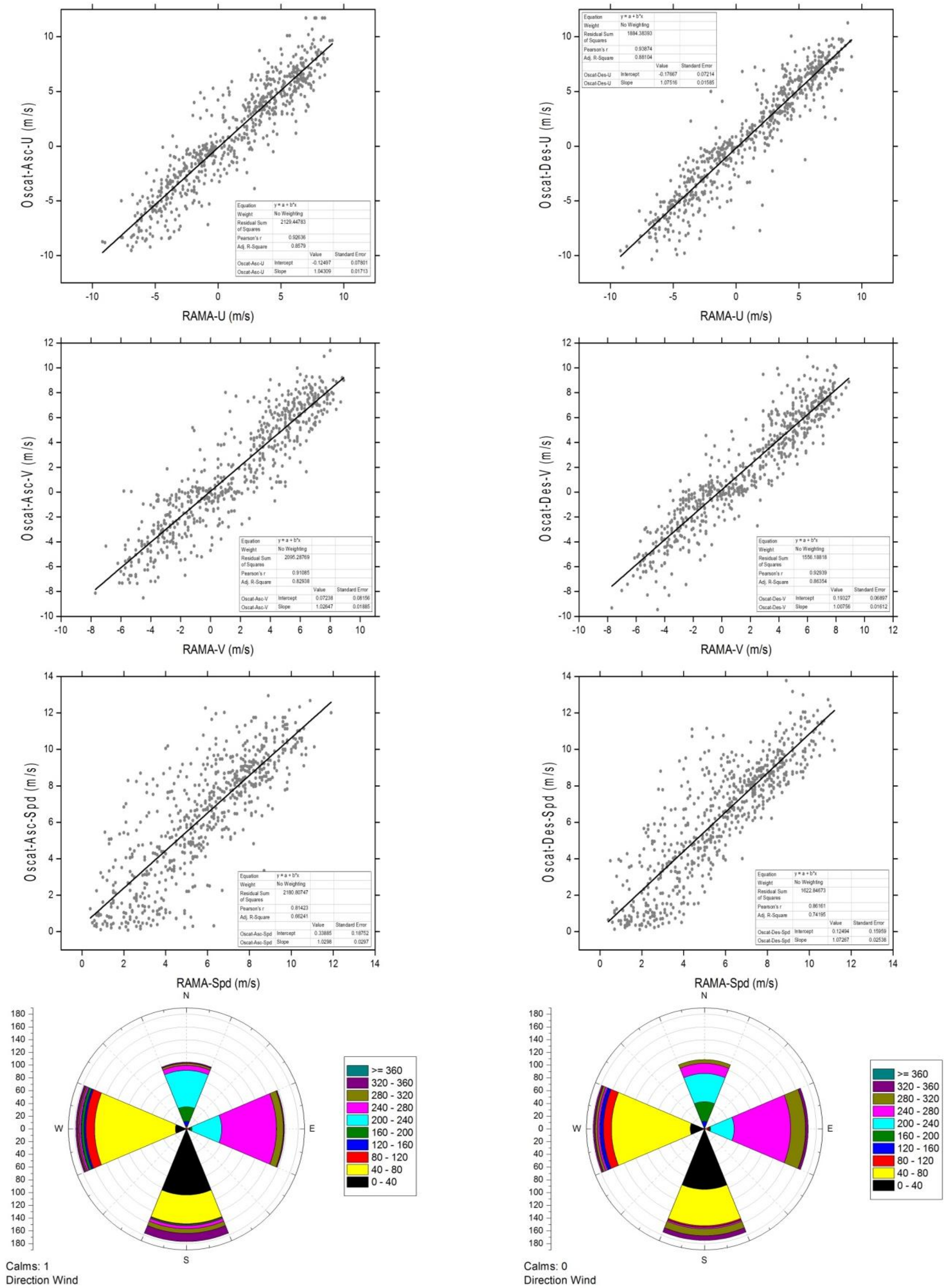

Figure 5: Same as Figure 2, but for buoy location: 8° N, 90° E

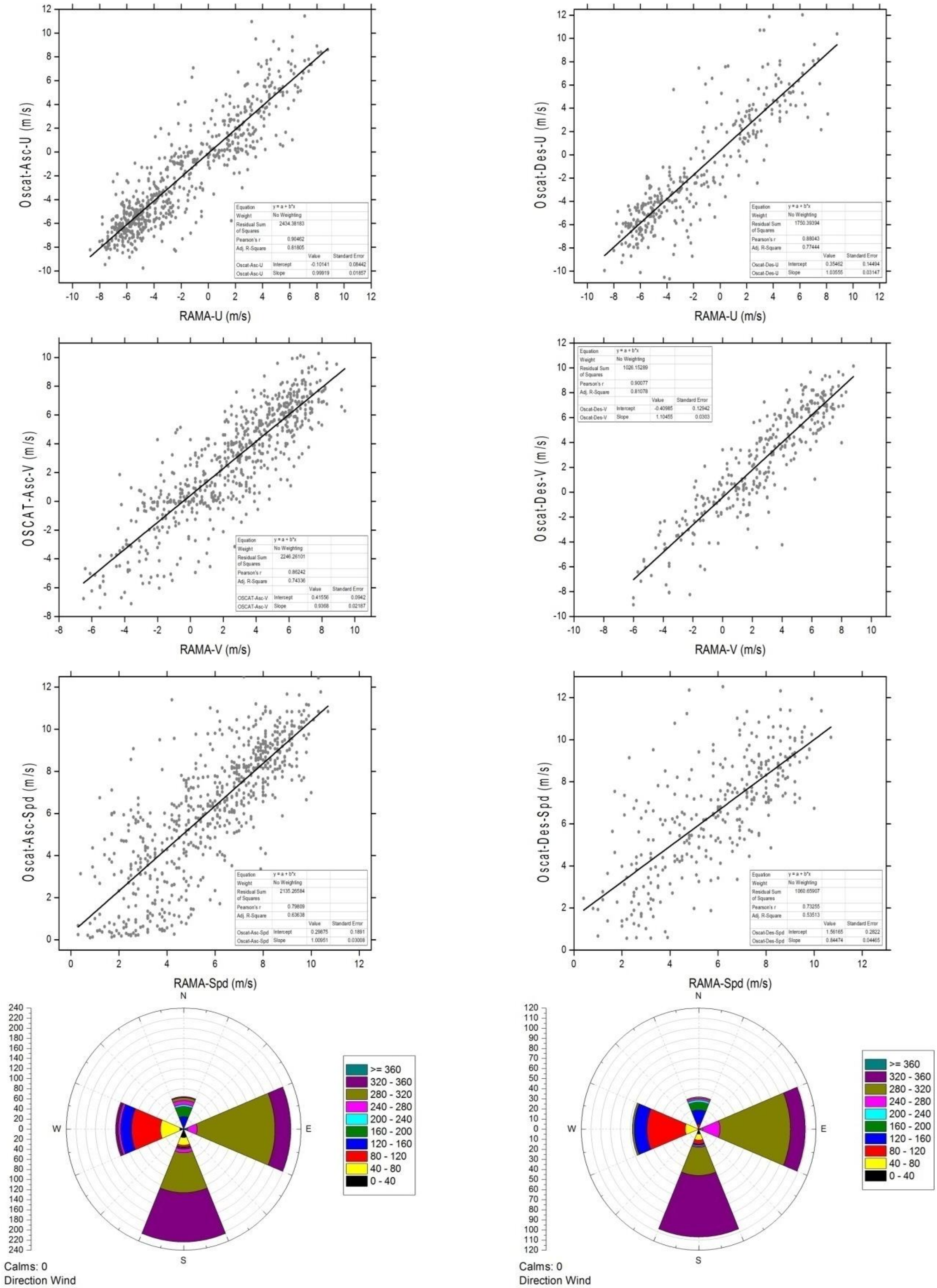

Figure 6: Same as Figure 2, but for buoy location: 8° S, 55° E

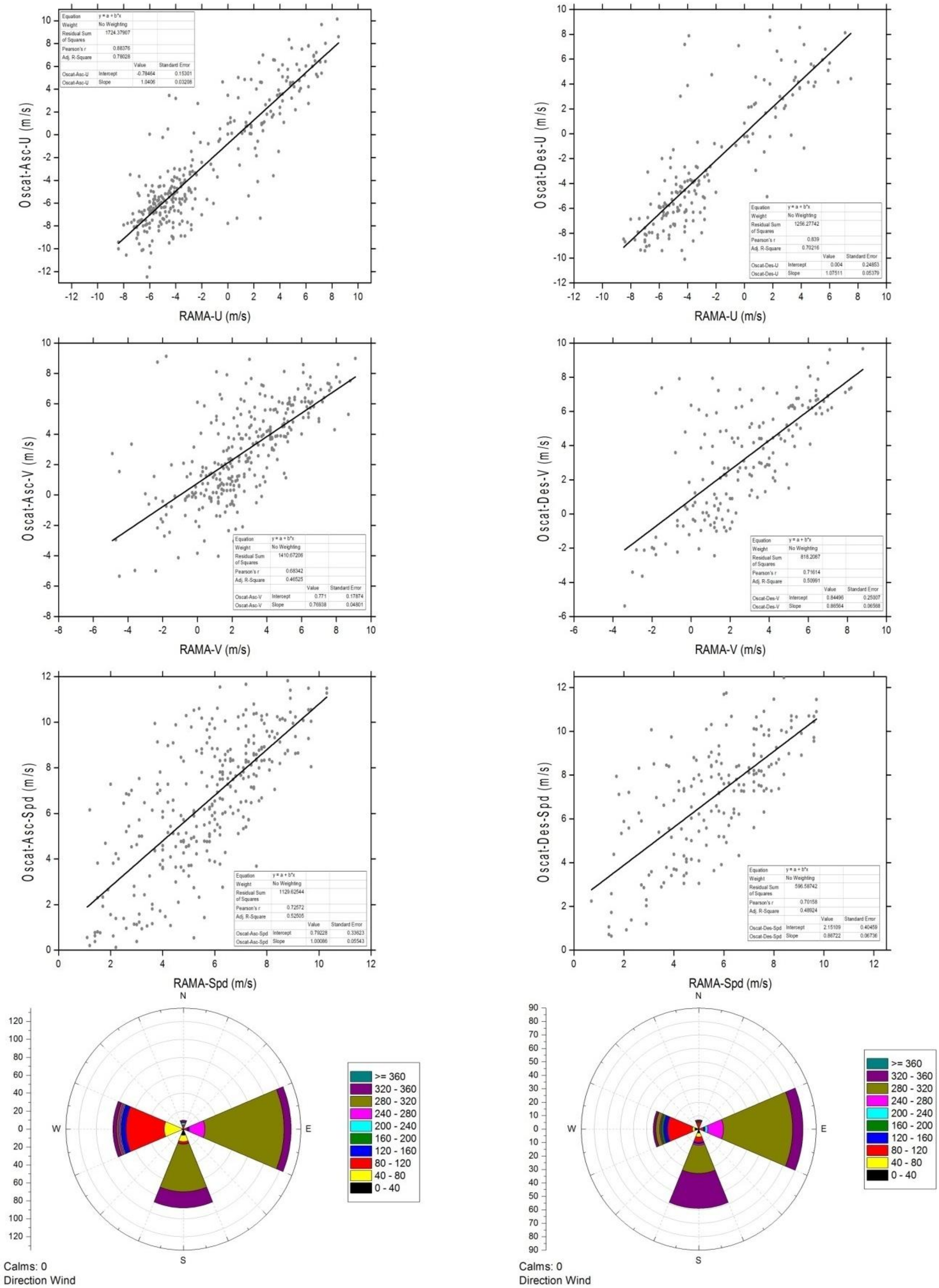

Figure 7: Same as Figure 2, but for buoy location: 8° S, 80.5° E

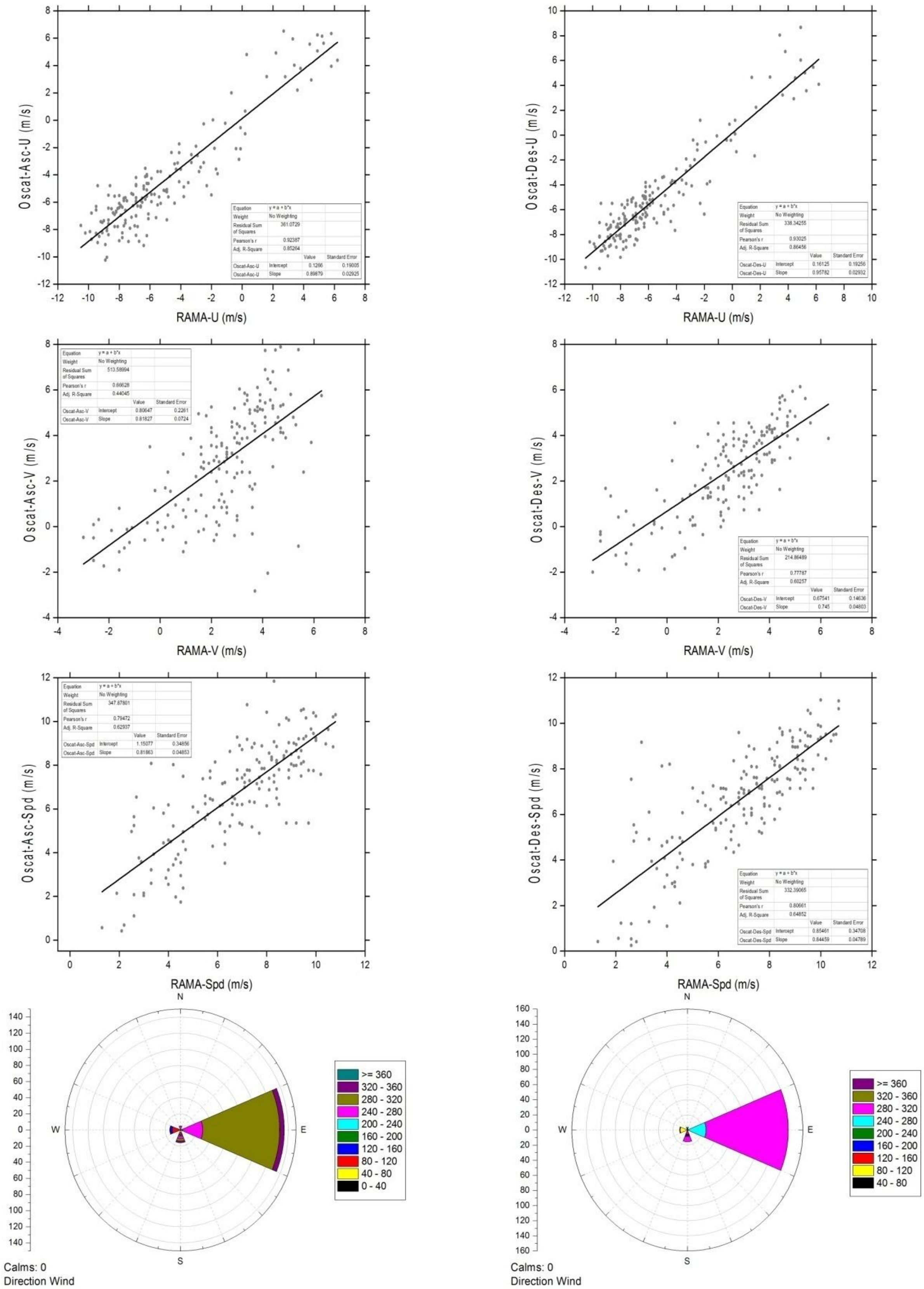

Figure 8: Same as Figure 2, but for buoy location: 8° S, 100° E

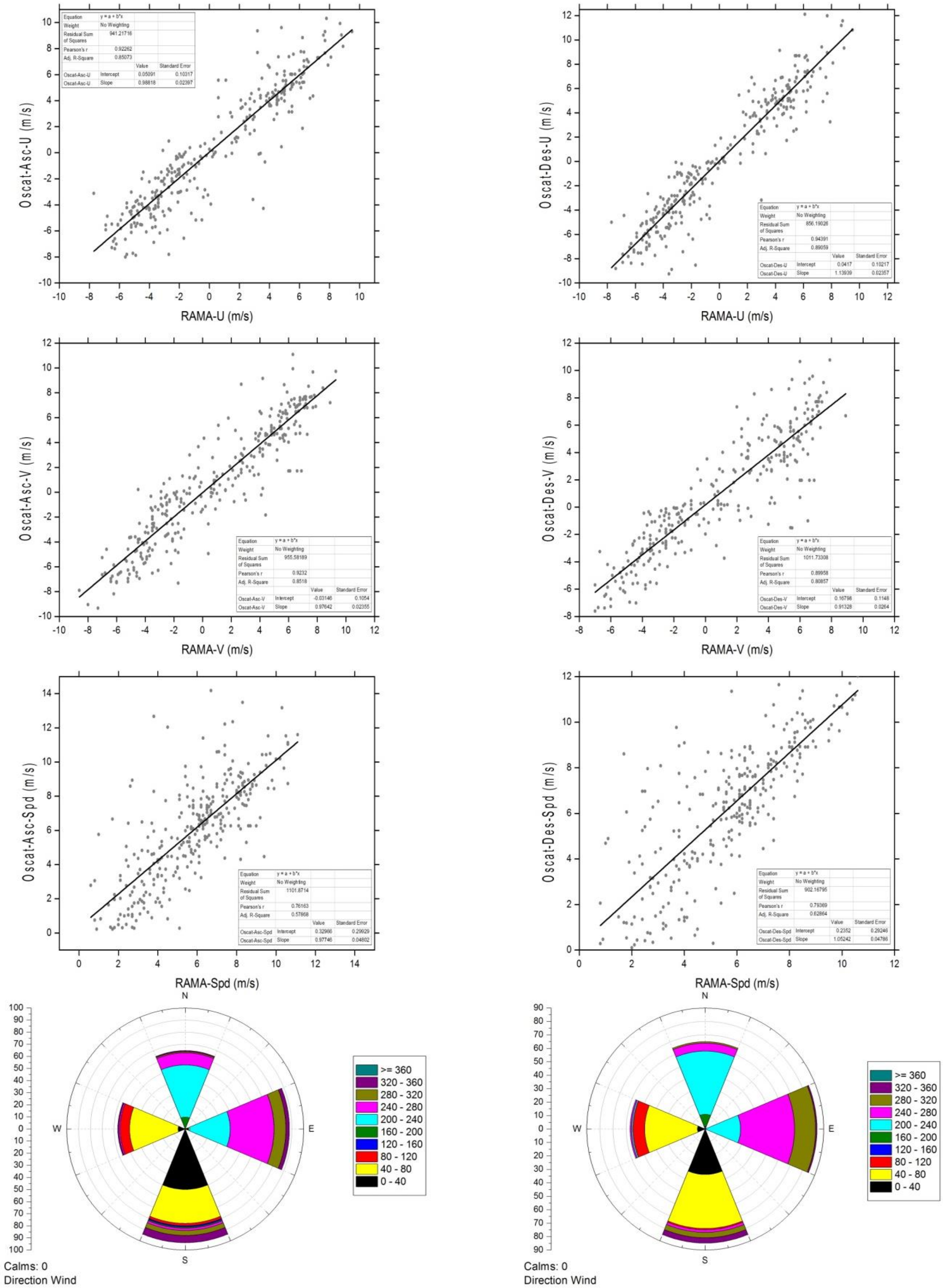

Figure 9: Same as Figure 2, but for buoy location: 12° N, 90° E

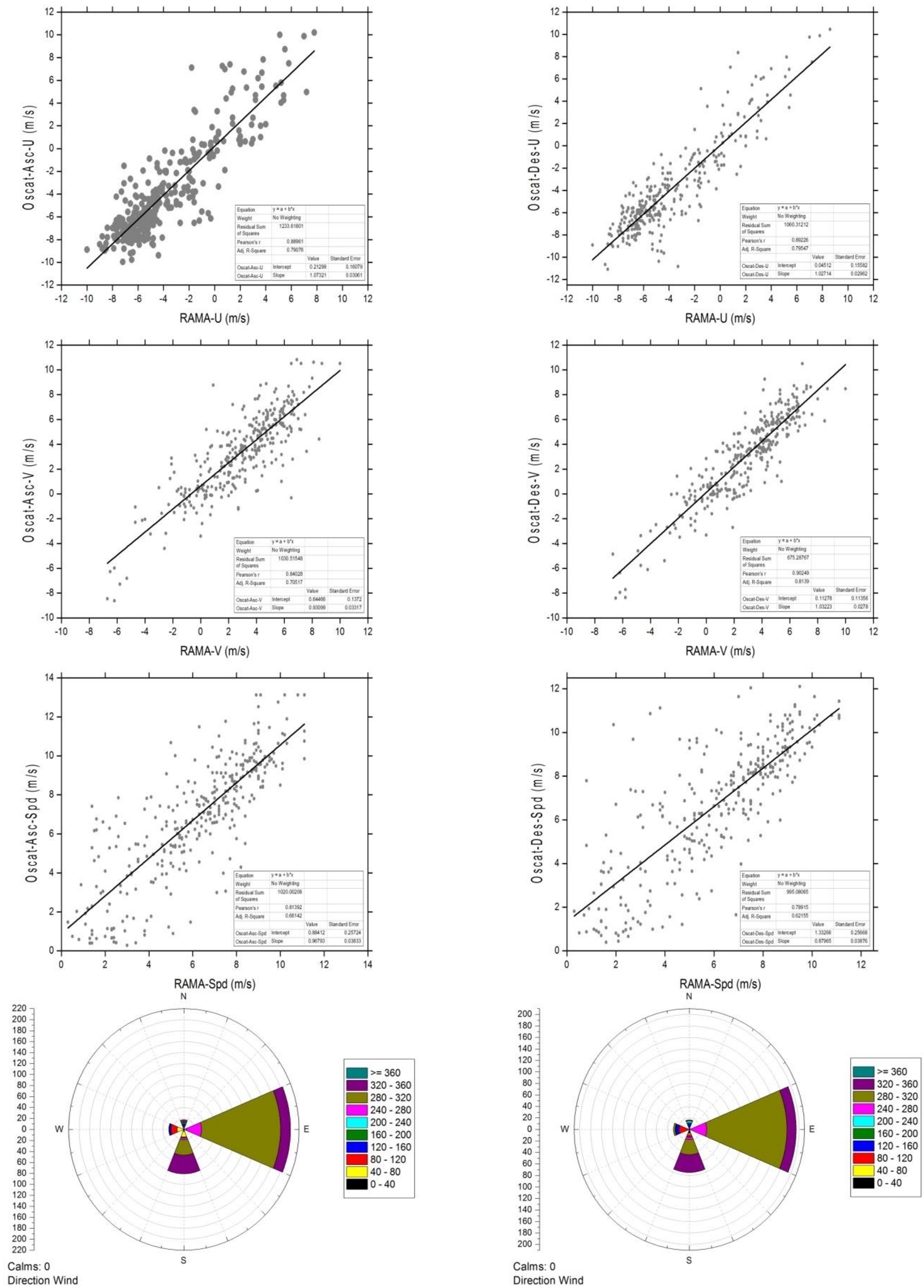

Figure 10: Same as Figure 2, but for buoy location: 12° S, 55° E

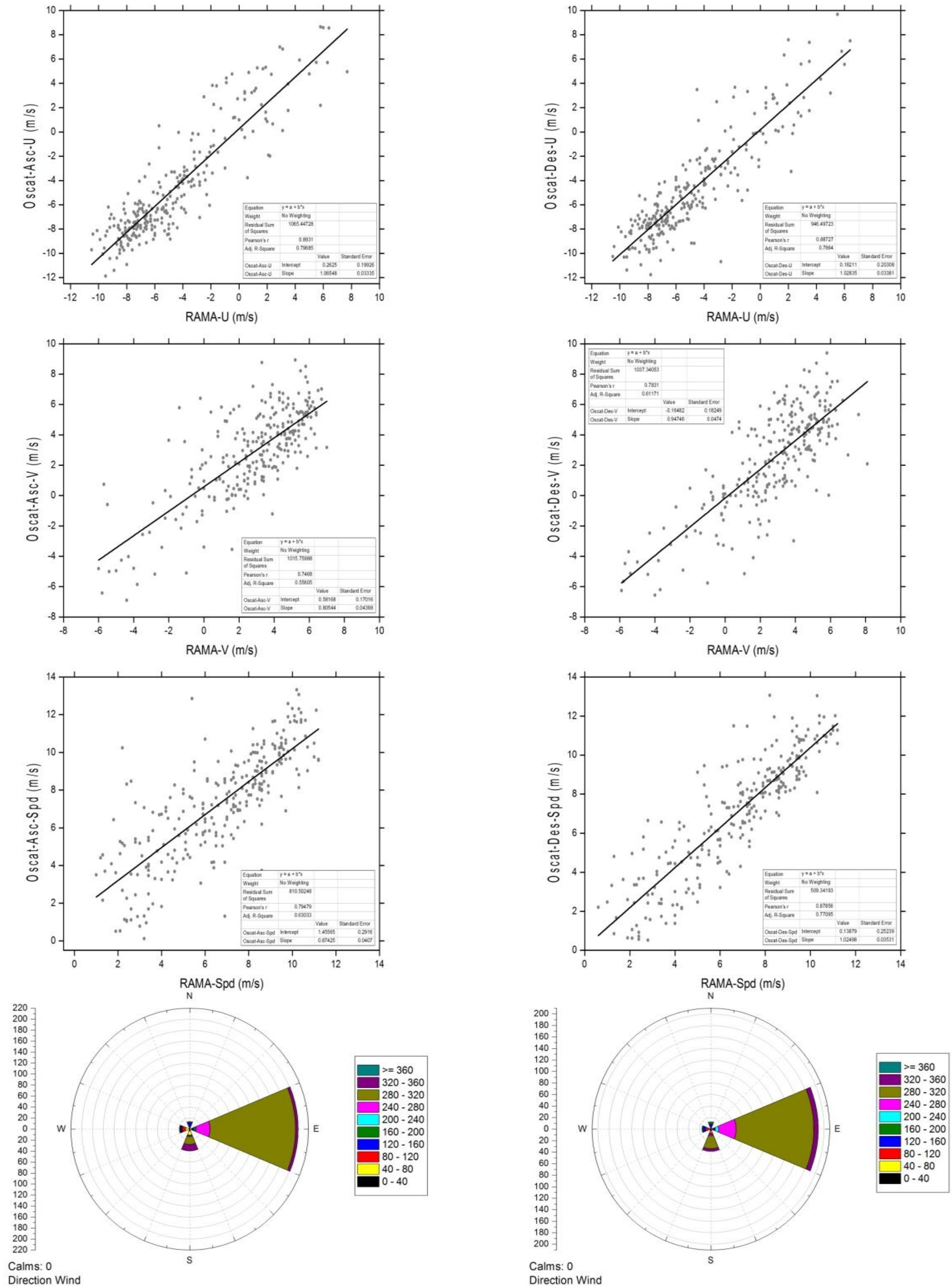

Figure 11: Same as Figure 2, but for buoy location: 12° S, 67° E

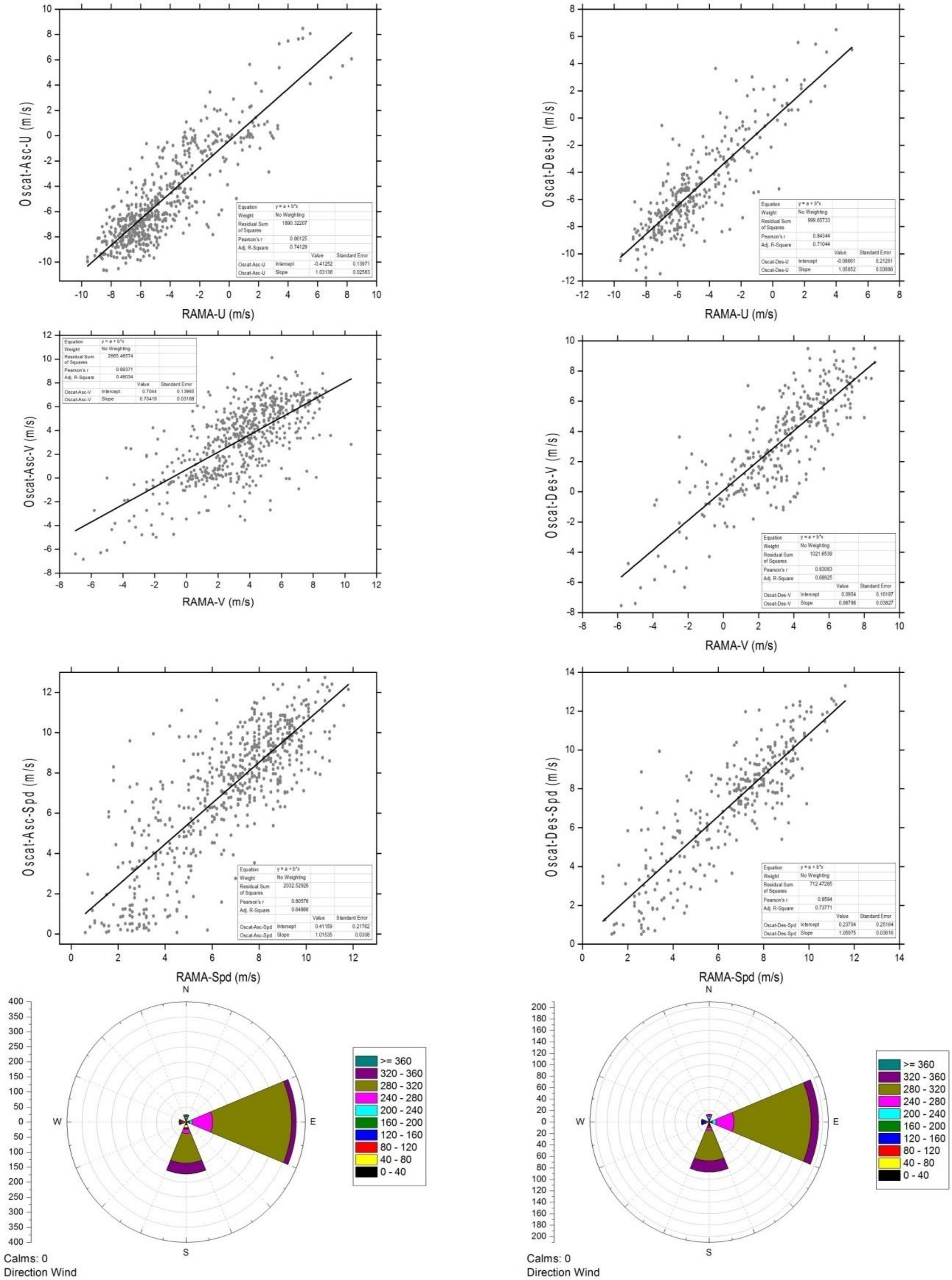

Figure 12: Same as Figure 2, but for buoy location: 12° S, 80.5° E

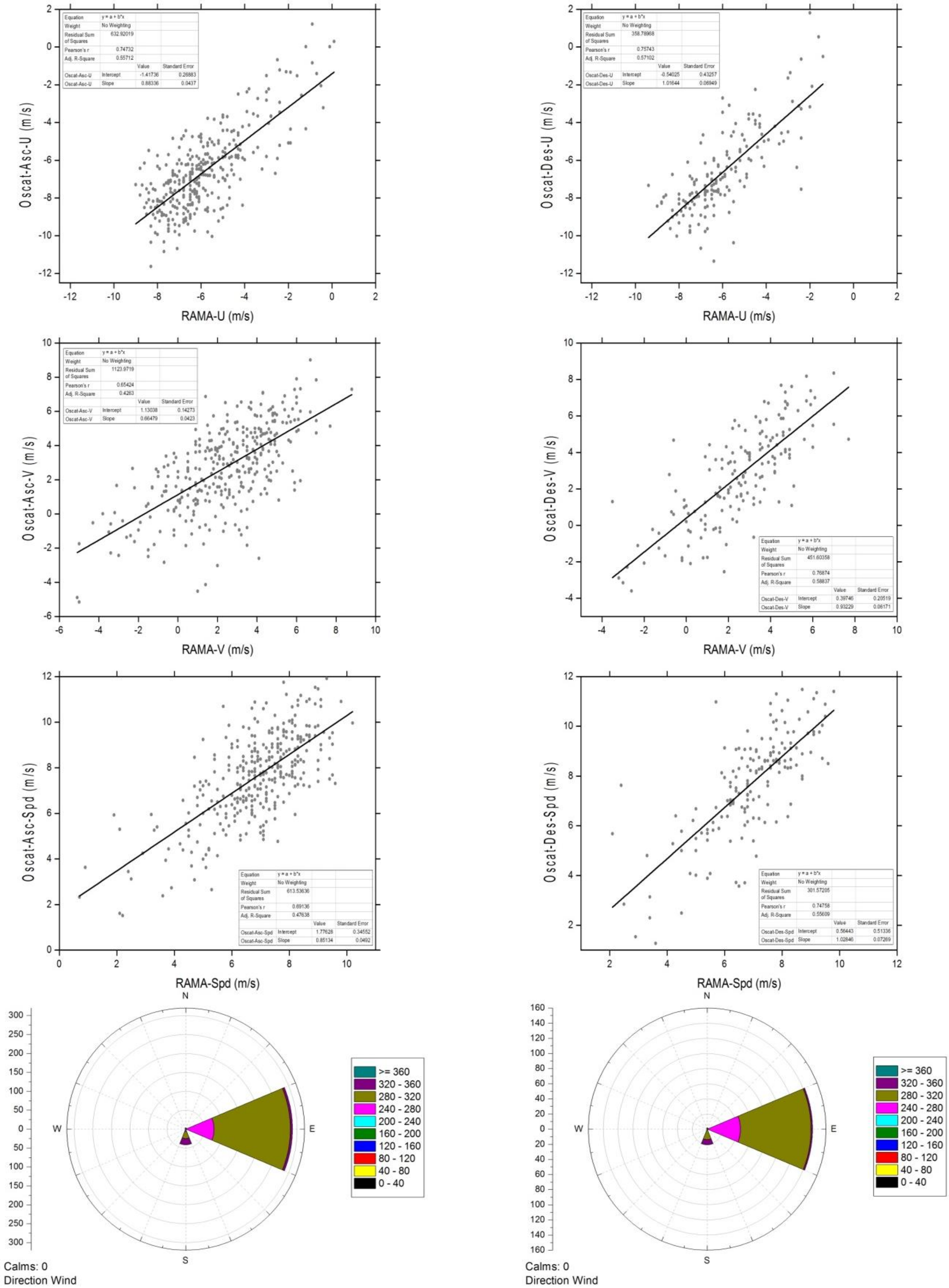

Figure 13: Same as Figure 2, but for buoy location: 12° S, 93° E

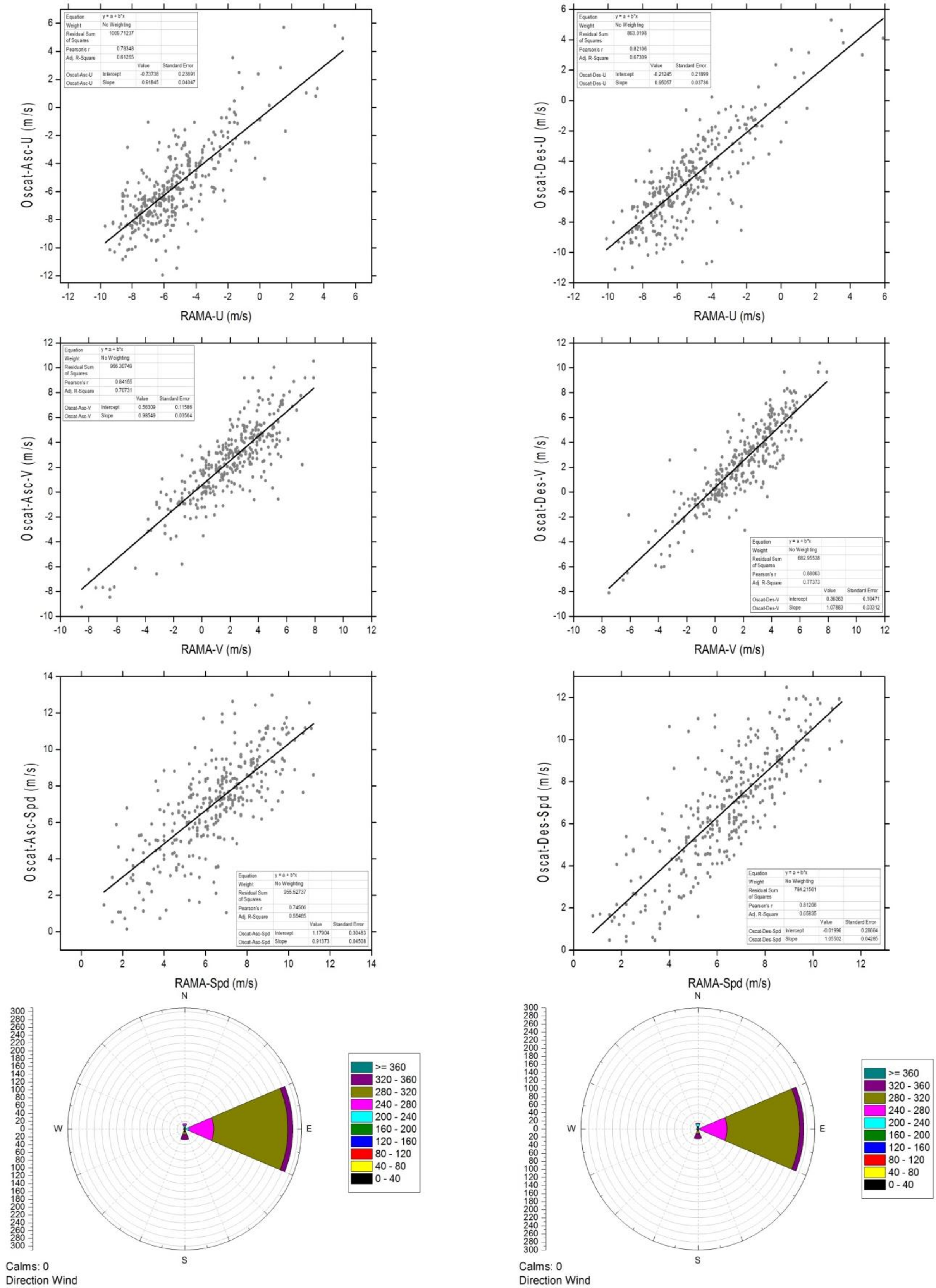

Figure 14: Same as Figure 2, but for buoy location: 16° S, 55° E

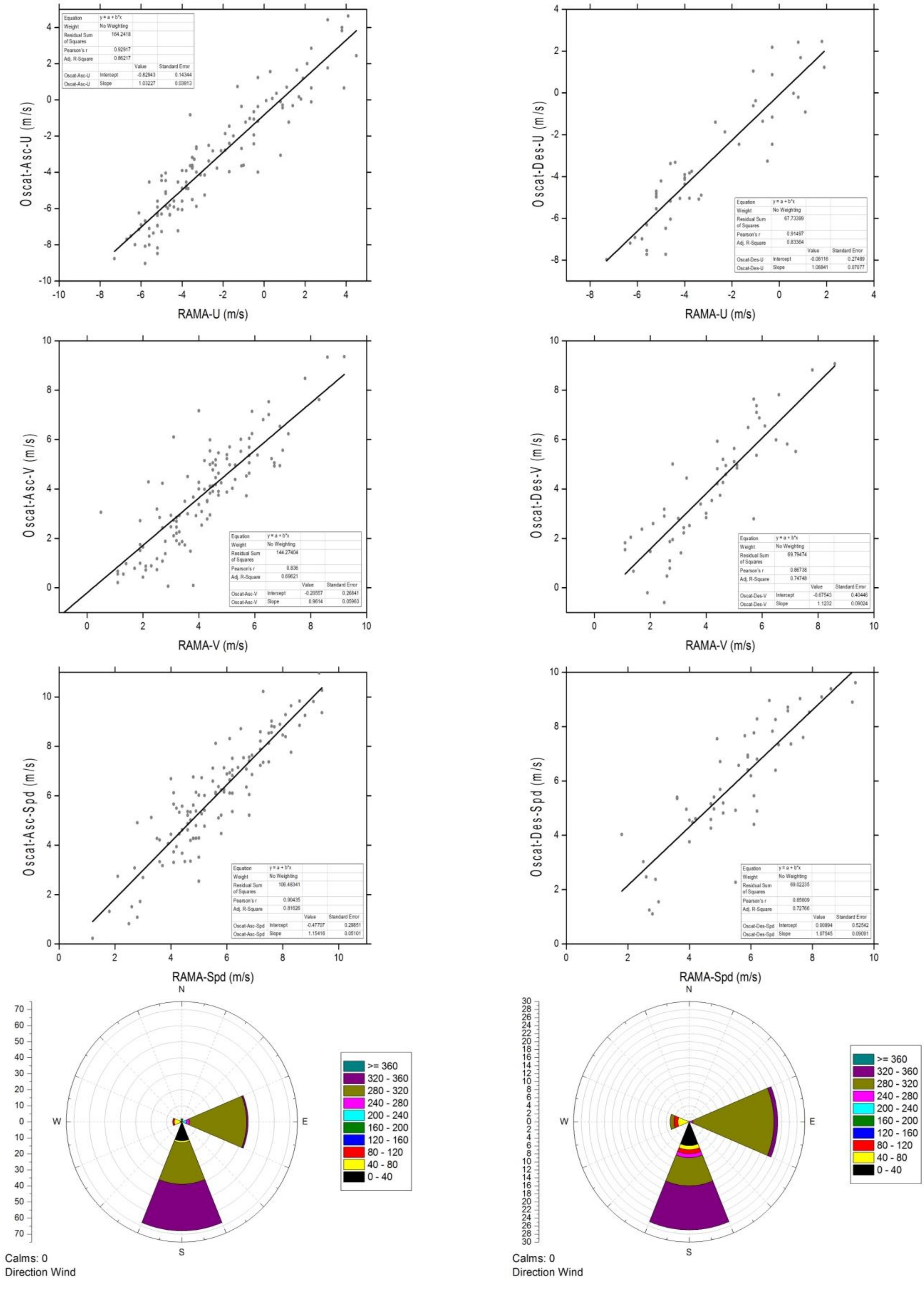

Figure 15: Same as Figure 2, but for buoy location: 12°S, 55° E

ANNEXURE - C

Comparisons between DIVA interpolated OSCAT wind composites with RAMA and NDBP buoys at different locations during the year 2012

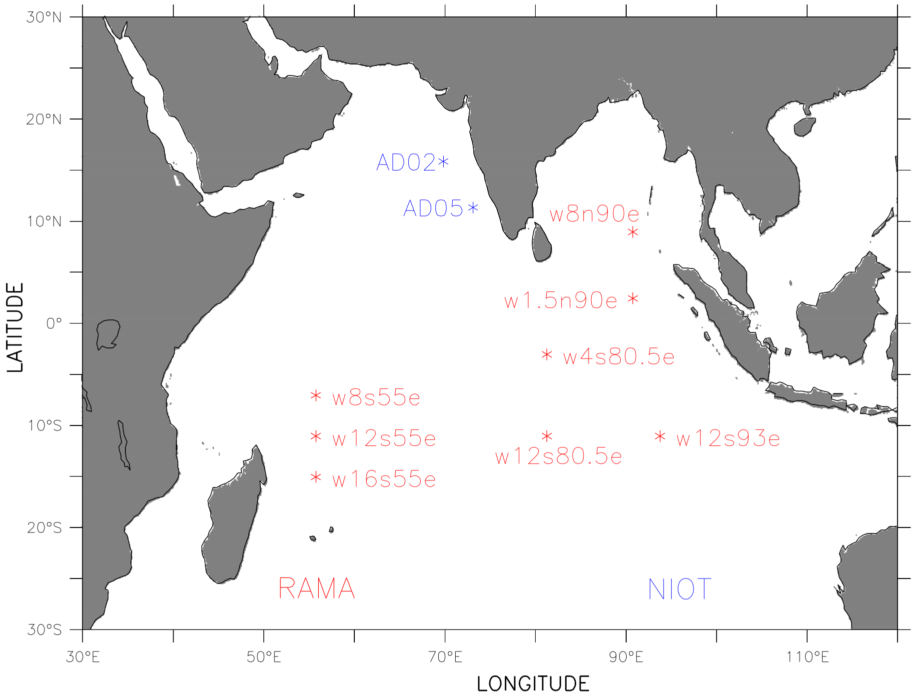

Figure 16: RAMA (red stars) and NDBP (blue stars) Buoy locations considered for comparison with DIVA generated OSCAT daily wind composites. The buoy ids are provided alongside.

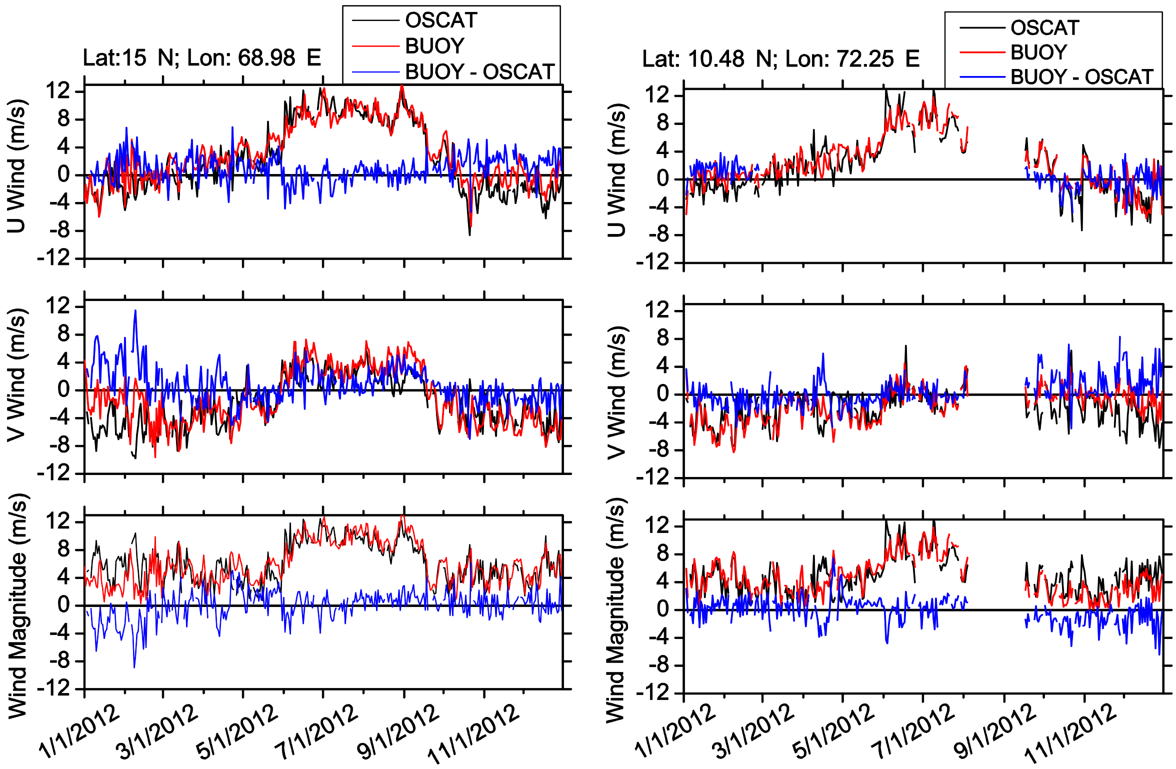

Figure 2: Comparison between DIVA interpolated OSCAT wind composites and those from **NDBP buoys** at (15 °N, 68.98 °E) and (10.48 °N, 72.25 °E) during January 2012

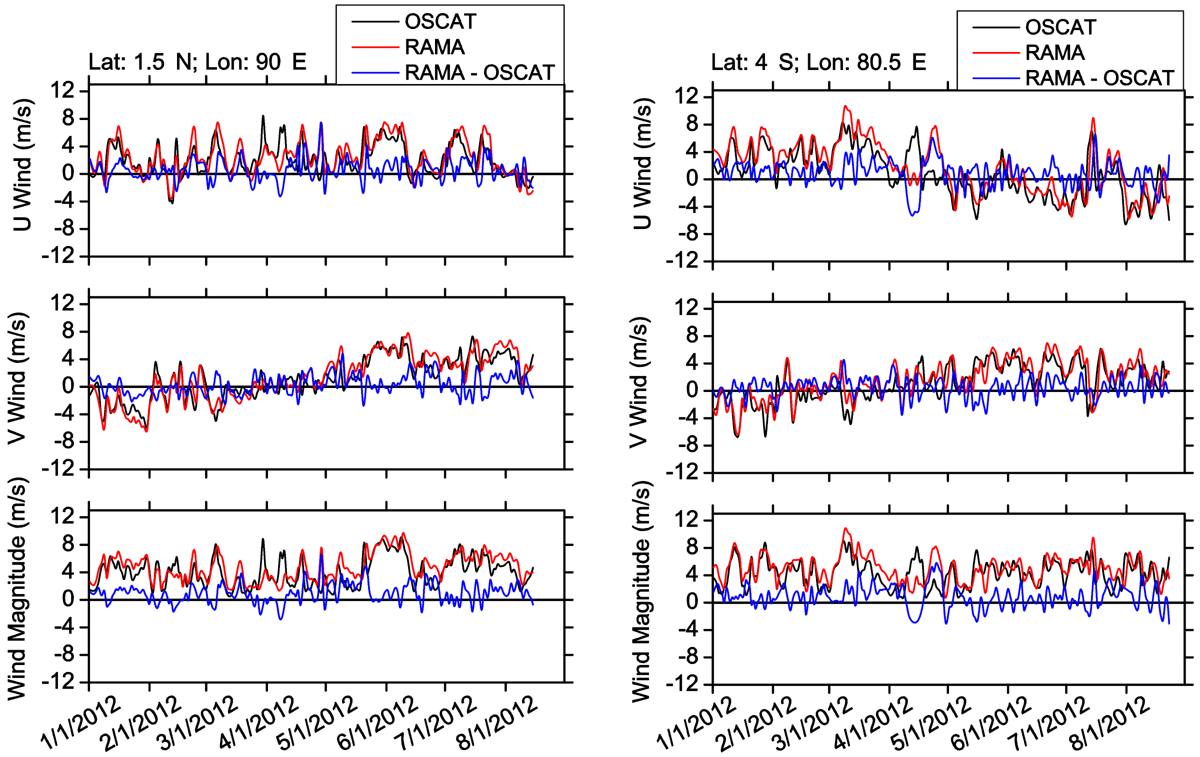

Figure 3: Comparison between DIVA interpolated OSCAT wind composites and those from **RAMA buoys** at (1.5 °N, 90 °E) and (4 °S, 80.5 °E) during January 2012

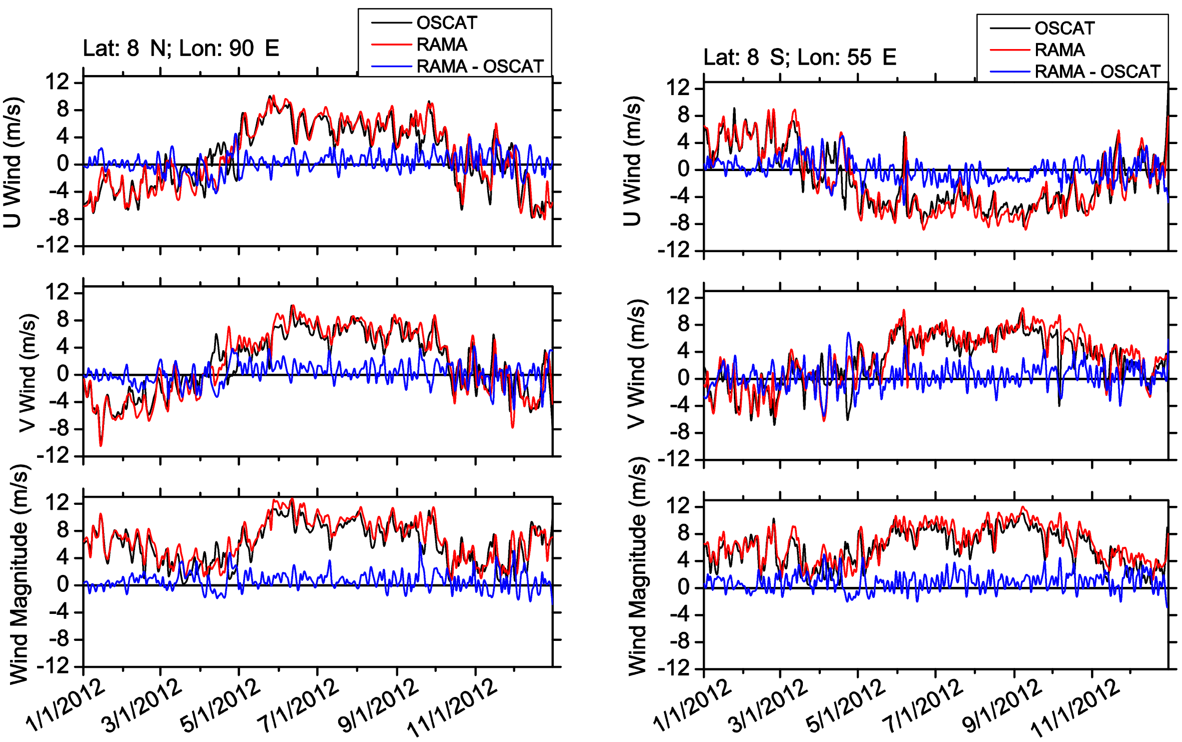

Figure 4: Same as Figure 3, but at (8 °N, 90 °E) and (8 °S, 55 °E)

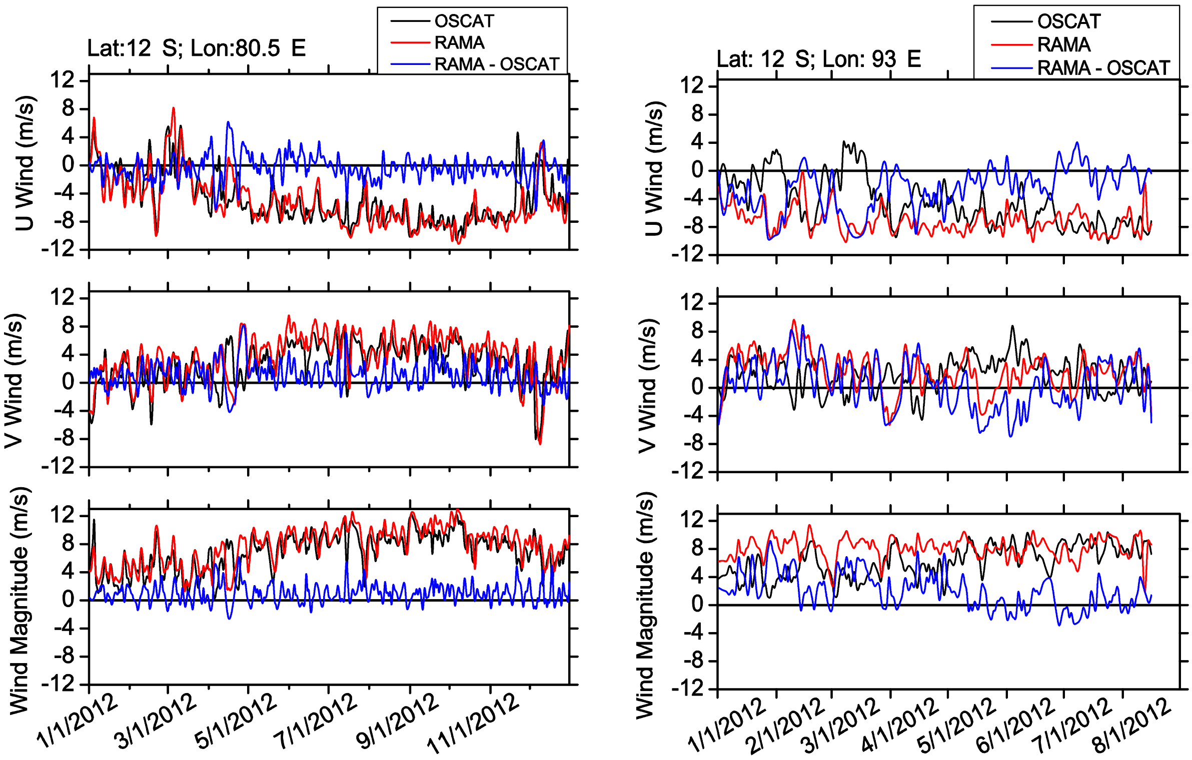

Figure 5: Same as Figure 3, but at (12 °S, 80.5 °E) and (12 °S, 93 °E)

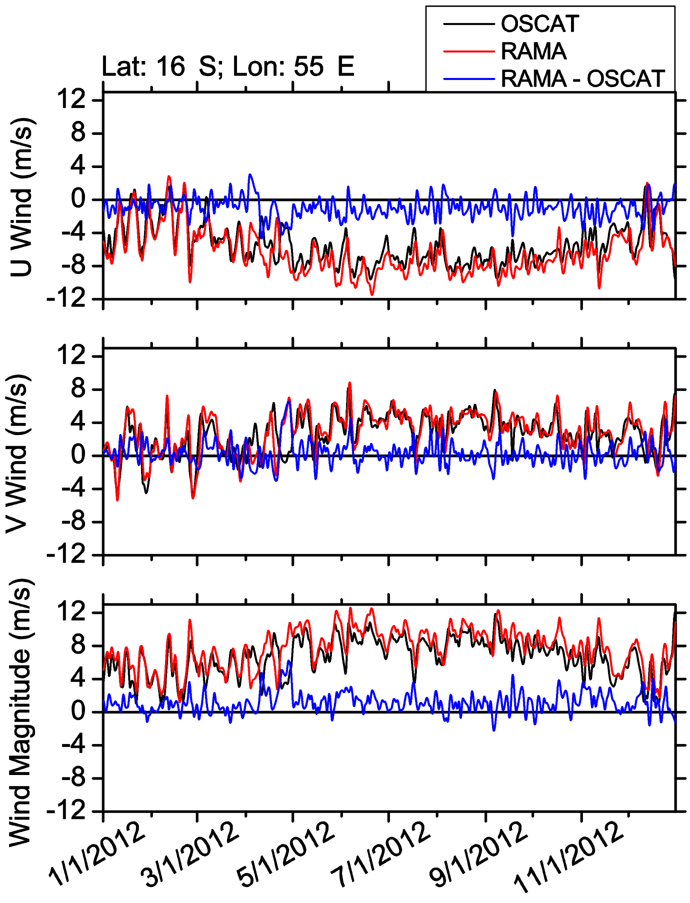

Figure 6: Same as Figure 3, but at (16 °S, 55 °E)

Table 1: Statistics of comparison between DIVA interpolated OSCAT daily wind composites and Buoy measured winds for the year 2012

Buoy ID	Lat.	Lon.	RMSD (m/s)			BIAS (m/s)			Correlation		
			U	V	Mag.	U	V	Mag.	U	V	Mag.
w1.5n90e	1.5 °N	90 °E	2.30	1.89	2.18	0.42	0.20	0.74	0.64	0.85	0.60
w4s80.5e	4 °S	80.5 °E	2.75	2.31	2.32	0.85	0.51	0.61	0.75	0.71	0.47
w8n90e	8 °N	90 °E	2.03	2.15	1.89	0.29	0.16	0.62	0.91	0.90	0.84
w8s55e	8 °S	55 °E	2.50	2.69	2.05	-0.09	0.47	0.76	0.86	0.77	0.77
W12s55e	12 °S	55 °E	2.53	1.99	2.19	-0.87	0.18	0.84	0.84	0.81	0.77
W12s80.5e	12 °S	80.5 °E	2.61	3.11	2.33	-0.44	0.97	0.79	0.76	0.60	0.71
W12s93e	12 °S	93 °E	4.98	4.08	3.57	-2.76	0.43	1.95	0.09	-0.05	0.01
W16s55e	16 °S	55 °E	2.03	2.31	2.04	-0.89	0.33	0.98	0.79	0.65	0.74
AD02	15 °N	68.98 °E	2.09	2.81	2.09	0.88	0.73	-0.04	0.93	0.74	0.74
AD05	10.48 °N	72.25 °E	1.89	2.20	1.97	0.50	0.31	-0.21	0.89	0.57	0.72

Table 2: Standard Deviations in DIVA interpolated OSCAT daily wind composites and Buoy measured winds for the year 2012

Buoy ID	Lat.	Lon.	Standard Deviation (m/s)					
			Buoy			OSCAT		
			U	V	Mag.	U	V	Mag.
w1.5n90e	1.5 °N	90 °E	2.75	3.51	2.17	2.59	3.16	2.37
w4s80.5e	4 °S	80.5 °E	3.84	2.94	2.12	3.59	2.96	2.22
w8n90e	8 °N	90 °E	4.92	5.02	3.03	4.72	4.51	3.02
w8s55e	8 °S	55 °E	4.79	4.01	2.74	4.37	3.74	2.81
W12s55e	12 °S	55 °E	4.35	3.36	3.14	3.93	3.09	2.81
W12s80.5e	12 °S	80.5 °E	3.65	3.38	2.87	3.75	3.19	2.90
W12s93e	12 °S	93 °E	1.96	2.96	1.70	3.80	2.70	2.47
W16s55e	16 °S	55 °E	2.94	2.82	2.51	2.78	2.62	2.46
AD02	15 °N	68.98 °E	4.24	3.94	2.93	4.93	3.48	2.88
AD05	10.48 °N	72.25 °E	3.73	2.37	2.66	4.09	2.35	2.62

ANNEXURE - D

Sample Wind Speed and other derived products from DIVA interpolated OSCAT daily wind composites at 50 km and 25 km resolutions on 6th May (Day No. 126) 2013

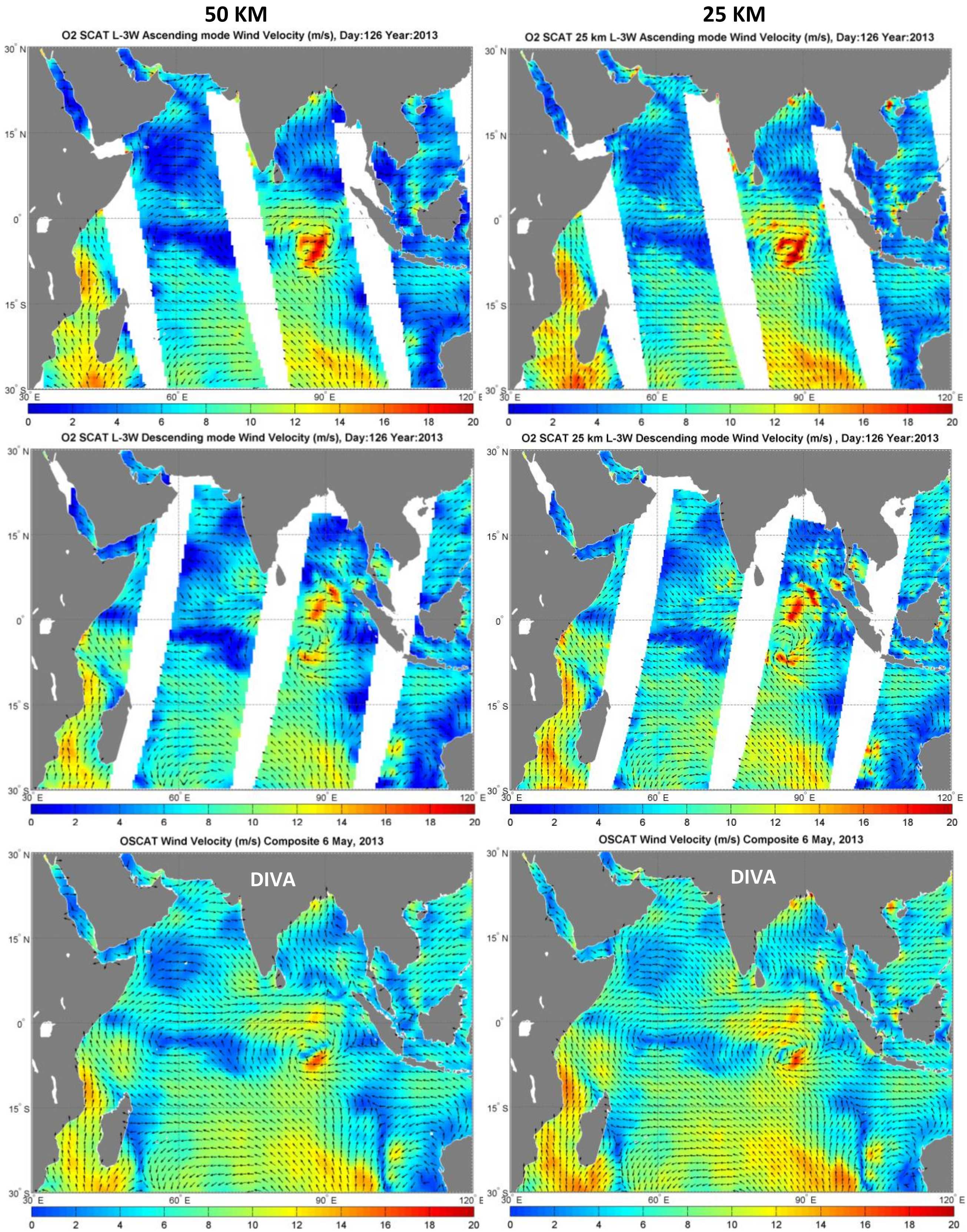

Figure 1: OSCAT Wind Speed Vectors

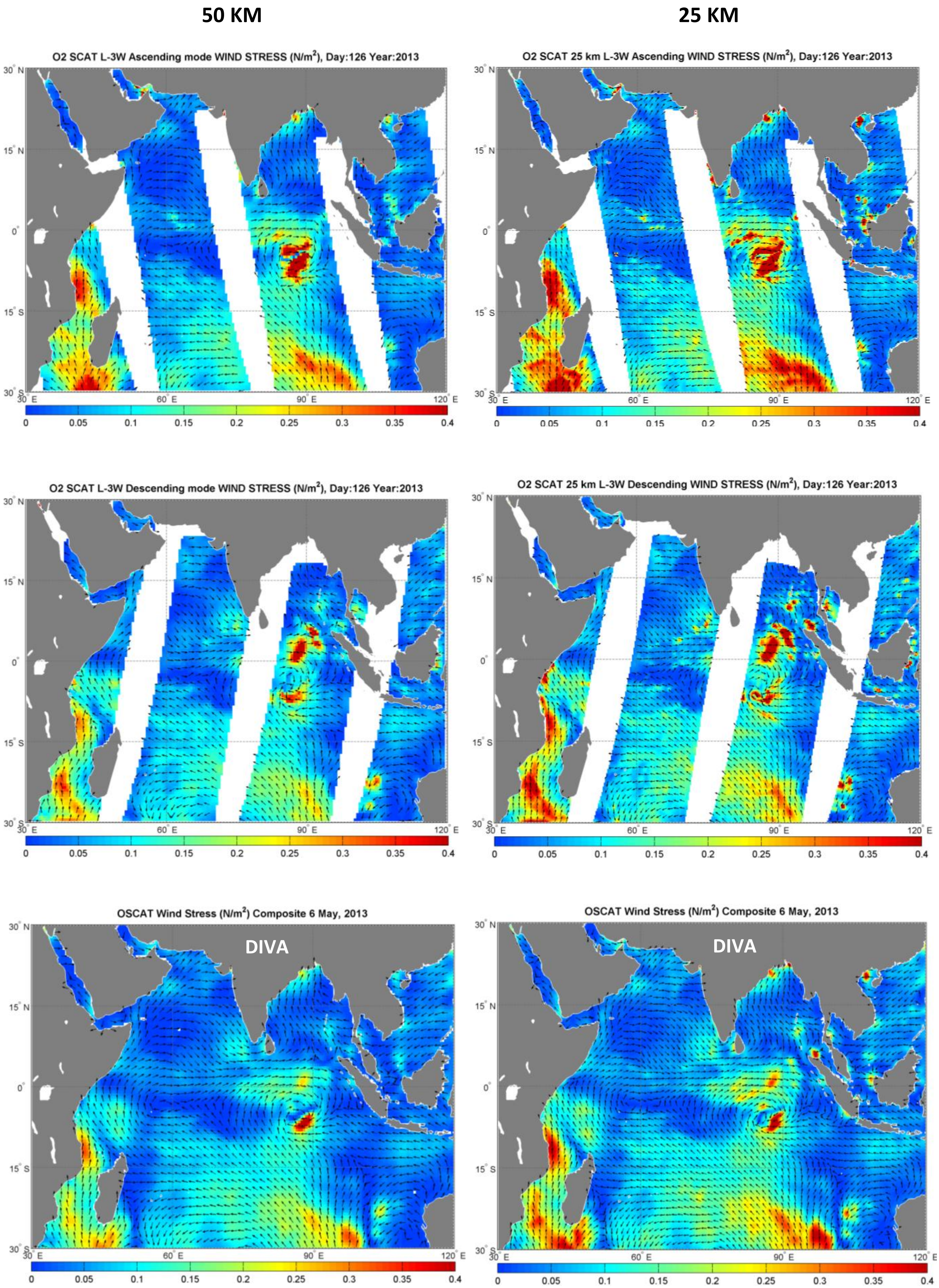

Figure 2: OSCAT Wind Stress Vectors

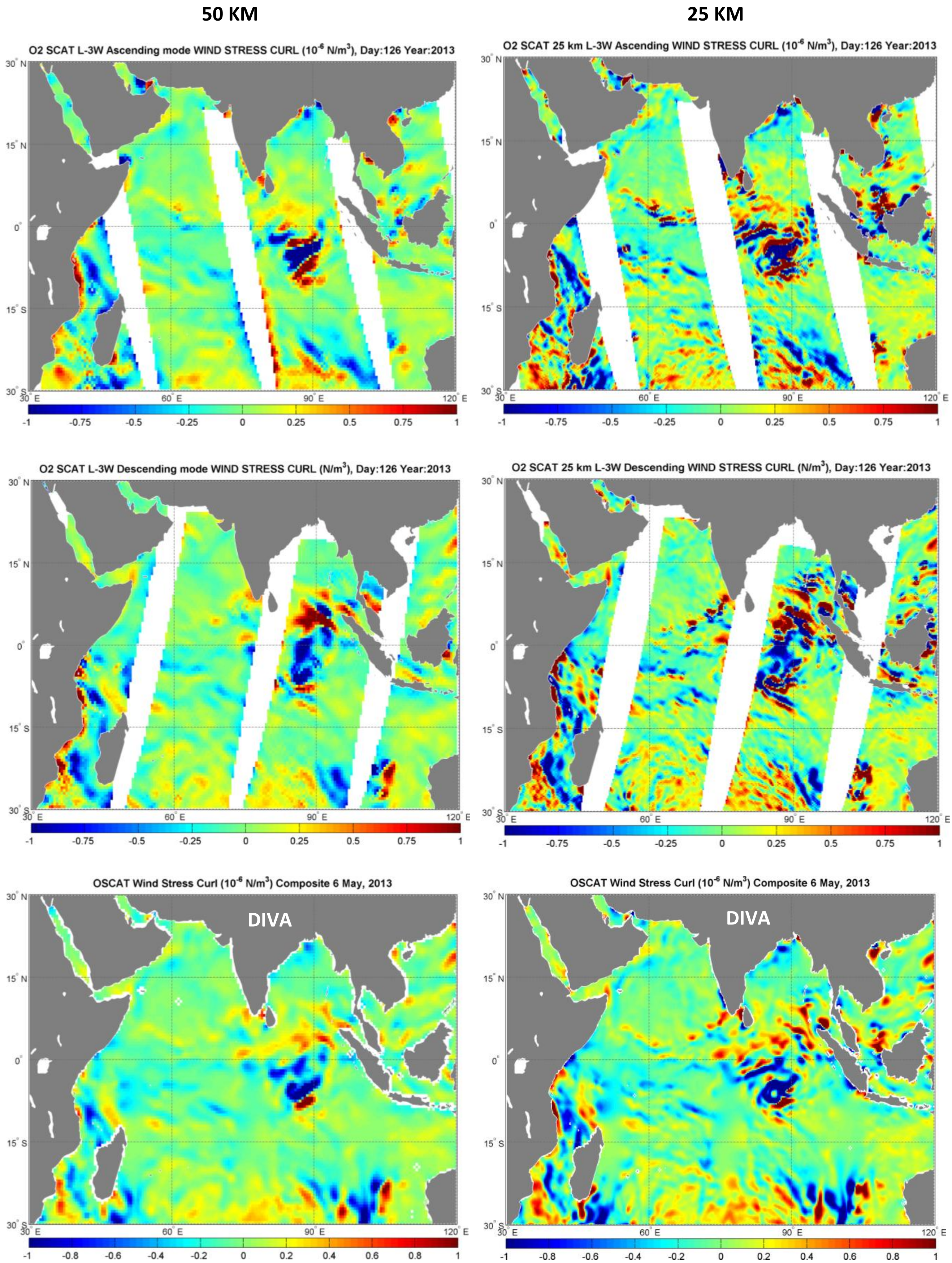

Figure 3: OSCAT Wind Stress Curl

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Ocean Sciences Group
Earth & Climate Science Area
National Remote Sensing Centre
ISRO (Govt. of India, Dept. of Space)
Balanagar, Hyderabad-500037, INDIA