NGI FILE #12-NGI2-24

Project Title: Assessing Statistical Climate Variability from the TAO Buoy Array

Project Lead (PI) name, affiliation, email address: Pat Fitzpatrick, MSU, fitz@gri.msstate.edu

Project objectives and goals

The objective is to determine the statistical oceanographic variability in the upper 500 meters of the water column in the Central Pacific Ocean over approximately the past two decades. A statistical analysis of equatorial Pacific data for 65 TAO/TRITON sites (Fig. 1) has been performed. The results have been provided to NDBC for guidance in their quality control assessments.

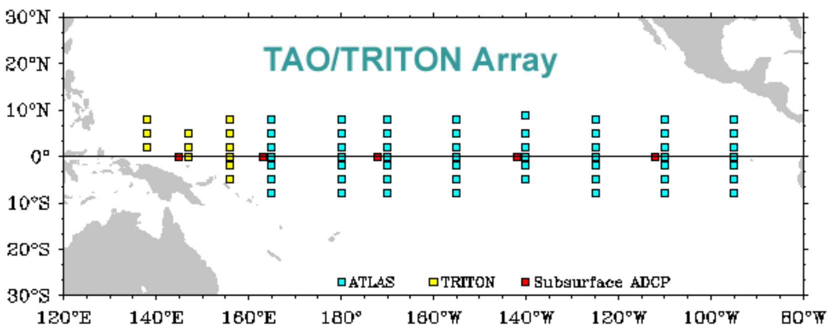


Figure 1. Locations of the buoys analyzed in this study. From http://tao.noaa.gov/images/tao-array-huge.gif

Description of research conducted during the reporting period and milestones accomplished and/or completed

The following is a list of milestones achieved during this project for longwave radiation, downwelling shortwave radiation, precipitation, surface meteorology values (air temperature, wind speed and direction, surface water temperature, relative humidity), subsurface salinity, and subsurface water temperature. Only data with quality codes of 1 (highest quality), 2 (default quality), or 3 (adjusted data) are used with source codes of 2 (derived from real-time), 5 (recovered from instrument, delayed mode), or 6 (derived from instrument, delayed mode). Most products are embedded in PowerPoints or Excel files are mass-generated using a combination of Microsoft's Visual Basic for Application (VBA) code, the R statistical language, the Generic Mapping Tools (GMT), and shell scripts. The products consist of:

i. Box plots and whiskers. The box ranges from the 25^{th} to 75^{th} percentiles, known as the interquartile range, with a line depicting the median. The arms of the box plot extend out to all observations within 1.5 times the interquartile range above the 75^{th} percentile, and the same distance below the 25^{th} percentile. Points outside those bands are outliers.
ii. Histograms.
iii. Temporal scatterplots

iv. Overlays of El Niño Climate Indices

v. Correlation matrices with bivariate scatter plots below the diagonal, histograms on the diagonal, and correlation values above the diagonal. Correlation ellipses are also shown.

vi. Scatterplots of variables moderately to highly correlated (r>|±0.7|) to Climate Indices, including correlation coefficient, regression equation, confidence intervals, and predictions intervals. The confidence interval provides the bounded values for the mean of all y(x), while the prediction interval gives the bounds of any future individual y(x). For large samples, the confidence interval closely corresponds to the predicted value ± twice the root mean square error, but is larger for small samples as in these buoy datasets.

vii. Spatial plots of ENSO teleconnection correlations, including depth patterns

viii. Tables for lifetime of buoy, and monthly statistic metrics for lifetime of buoy, in Excel spreadsheets, with links to PowerPoints of ENSO correlations.

The climate indices include Niño 3, Niño 3.4, and Niño 4 (Fig. 2), as well as the Southern Oscillation Index (SOI), the Trans-Niño Index (TNI), and the Oceanic Niño Index (ONI), all downloaded from http://www.esrl.noaa.gov/psd/data/climateindices/list/ .

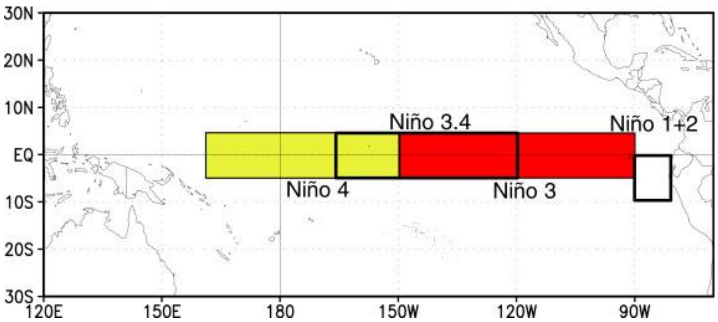


Figure 2. Locations of the Niño regions from http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/Niño_regions.shtml .

Milestones are:

Milestone A: *Longwave and downwelling shortwave radiation*: (11 buoys available for longwave, 23 for shortwave)

1) Box and whisker plots, summarized in one PowerPoint for all relevant buoys (Fig. 3).

2) Box and whisker plots two-minute observations with hour on x axis, summarized in a PowerPoint for each buoy (in a sub-directory). Nighttime values for shortwave (0 Wm^{-2}) are not included in the statistics (Fig. 3).

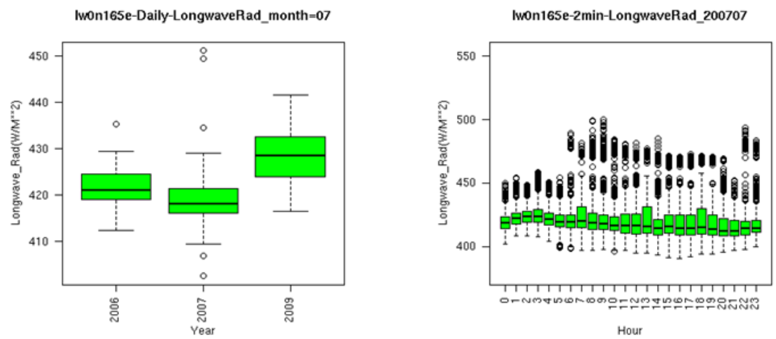


Figure 3. Example of longwave radiation box and whisker plots for the buoy located on the equator at 165°E. An instance of daily observations with year on x axis for July is shown on the left, and two-minute observations with hour on x axis for July 2007 is shown on the right. The box ranges are from the 25th to 75th percentiles, known as the interquartile range, with a line depicting the median. The arms of the box plot extend out to all observations within 1.5 times the interquartile range above the 75th percentile, and the same distance below the 25th percentile. Points outside those bands are outliers.

Milestone B: *Rain rate*: (28 buoys)

Histogram plots (Fig. 4) are performed for each buoy in sub-directories on:

1) 10-minute observations tallied in each year.
2) 10-minute observations tallied in each month.

Because many days are rain-free, the plots have a lognormal or gamma distribution. Unfortunately, a few observations contain contaminated negative values. Since the data quality is questionable, further analysis is not performed.

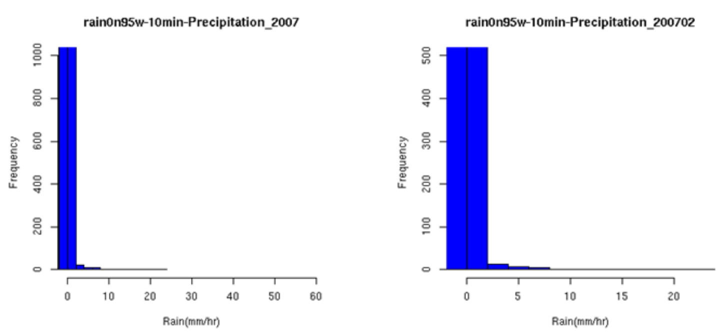


Figure 4. Example of histogram plots for rain rate (mm h^{-1}) in ten-minute intervals for the buoy located on the equator at 95°W. An instance of annual data distribution in 2007 is shown on the left, and February 2007 shown on the right. Note the contaminated negative values.

Milestone C: *Surface meteorology* (65 buoys)

In main directory (all plots are done for 00 UTC and 12 UTC):

1) Excel spreadsheet of SST and air temperature climate index correlations when r>|±0.7|, shown in Fig. 5. Figure 6 shows a scatterplot of these results.

K68 f_x =AVERAGE(K2:K65)

	A	B	C	D	E	F	G	H	I	J	K
1	TAO stations - Surface Meteorogical Variables SST and AIRT Correlations with Climate Indices > 0.7										
2	1	met0n110w.NINO3.SST.00	0.93	met0n110w.NINO3.AIRT.00	0.94	-0.01		met0n110w.NINO3.SST.12	0.92	met0n110w.NINO3.AIRT.12	0.94
3	2	met0n125w.NINO3.4.SST.00	0.86	met0n125w.NINO3.4.AIRT.00	0.85	0.01		met0n125w.NINO3.4.SST.12	0.88	met0n125w.NINO3.4.AIRT.12	0.87
4	3	met0n125w.NINO3.SST.00	0.95	met0n125w.NINO3.AIRT.00	0.94	0.01		met0n125w.NINO3.SST.12	0.93	met0n125w.NINO3.AIRT.12	0.93
5	4	met0n140w.NINO3.4.SST.00	0.93	met0n140w.NINO3.4.AIRT.00	0.91	0.02		met0n125w.ONI.SST.12	0.76	met0n125w.ONI.AIRT.12	0.71
6	5	met0n140w.NINO3.SST.00	0.82	met0n140w.NINO3.AIRT.00	0.82	0		met0n140w.NINO3.4.SST.12	0.92	met0n140w.NINO3.4.AIRT.12	0.91
7	6	met0n140w.ONI.SST.00	0.85	met0n140w.ONI.AIRT.00	0.81	0.04		met0n140w.NINO3.SST.12	0.8	met0n140w.NINO3.AIRT.12	0.81
8	7	met0n155w.NINO3.4.SST.00	0.93	met0n155w.NINO3.4.AIRT.00	0.91	0.02		met0n140w.ONI.SST.12	0.85	met0n140w.ONI.AIRT.12	0.82
9	8	met0n155w.NINO4.SST.00	0.86	met0n155w.NINO4.AIRT.00	0.85	0.01		met0n155w.NINO3.4.SST.12	0.93	met0n155w.NINO3.4.AIRT.12	0.91
10	9	met0n155w.ONI.SST.00	0.92	met0n155w.ONI.AIRT.00	0.87	0.05		met0n155w.NINO4.SST.12	0.86	met0n155w.NINO4.AIRT.12	0.85
11	10	met0n170w.NINO3.4.SST.00	0.82	met0n170w.NINO3.4.AIRT.00	0.8	0.02		met0n155w.ONI.SST.12	0.92	met0n155w.ONI.AIRT.12	0.87
12	11	met0n170w.NINO4.SST.00	0.95	met0n170w.NINO4.AIRT.00	0.93	0.02		met0n170w.NINO3.4.SST.12	0.81	met0n170w.NINO3.4.AIRT.12	0.79
13	12	met0n170w.ONI.SST.00	0.88	met0n170w.ONI.AIRT.00	0.84	0.04		met0n170w.NINO4.SST.12	0.94	met0n170w.NINO4.AIRT.12	0.93
14	13	met0n180w.NINO4.SST.00	0.94	met0n180w.NINO4.AIRT.00	0.92	0.02		met0n170w.ONI.SST.12	0.88	met0n170w.ONI.AIRT.12	0.84
15	14	met0n95w.NINO3.SST.00	0.85	met0n95w.NINO3.AIRT.00	0.84	0.01		met0n180w.NINO4.SST.12	0.94	met0n180w.NINO4.AIRT.12	0.92
16	15	met2n110w.NINO3.SST.00	0.93	met2n110w.NINO3.AIRT.00	0.94	-0.01		met0n95w.NINO3.SST.12	0.86	met0n95w.NINO3.AIRT.12	0.86
17	16	met2n125w.NINO3.4.SST.00	0.84	met2n125w.NINO3.4.AIRT.00	0.8	0.04		met2n110w.NINO3.SST.12	0.93	met2n110w.NINO3.AIRT.12	0.94
18	17	met2n125w.NINO3.SST.00	0.94	met2n125w.NINO3.AIRT.00	0.94	0		met2n125w.NINO3.4.SST.12	0.87	met2n125w.NINO3.4.AIRT.12	0.81
19	18	met2n140w.NINO3.4.SST.00	0.94	met2n140w.NINO3.4.AIRT.00	0.92	0.02		met2n125w.NINO3.SST.12	0.93	met2n125w.NINO3.AIRT.12	0.93
20	19	met2n140w.NINO3.SST.00	0.78	met2n140w.NINO3.AIRT.00	0.8	-0.02		met2n140w.NINO3.4.SST.12	0.94	met2n140w.NINO3.4.AIRT.12	0.92
21	20	met2n140w.ONI.SST.00	0.82	met2n140w.ONI.AIRT.00	0.8	0.02		met2n140w.NINO3.SST.12	0.76	met2n140w.NINO3.AIRT.12	0.8
22	21	met2n155w.NINO3.4.SST.00	0.9	met2n155w.NINO3.4.AIRT.00	0.85	0.05		met2n140w.ONI.SST.12	0.83	met2n140w.ONI.AIRT.12	0.81
23	22	met2n155w.NINO4.SST.00	0.88	met2n155w.NINO4.AIRT.00	0.83	0.05		met2n155w.NINO3.4.SST.12	0.9	met2n155w.NINO3.4.AIRT.12	0.86
24	23	met2n155w.ONI.SST.00	0.87	met2n155w.ONI.AIRT.00	0.81	0.06		met2n155w.NINO4.SST.12	0.88	met2n155w.NINO4.AIRT.12	0.85
25	24	met2n170w.NINO3.4.SST.00	0.8	met2n170w.NINO3.4.AIRT.00	0.75	0.05		met2n155w.ONI.SST.12	0.88	met2n155w.ONI.AIRT.12	0.82
26	25	met2n170w.NINO4.SST.00	0.96	met2n170w.NINO4.AIRT.00	0.92	0.04		met2n170w.NINO3.4.SST.12	0.8	met2n170w.NINO3.4.AIRT.12	0.76
27	26	met2n170w.ONI.SST.00	0.86	met2n170w.ONI.AIRT.00	0.82	0.04		met2n170w.NINO4.SST.12	0.96	met2n170w.NINO4.AIRT.12	0.92
28	27	met2n180w.NINO4.SST.00	0.93	met2n180w.NINO4.AIRT.00	0.89	0.04		met2n170w.ONI.SST.12	0.86	met2n170w.ONI.AIRT.12	0.83

Figure 5. Portion of spreadsheet showing correlation comparisons of air temperature and SST when r≥+0.7. for 00 UTC, the SST indicators are in columns B and C, and air temperature is in columns D and E. The differences (SST minus air temperature) are shown in column F. 12 UTC is done in the same method to the right (image cutoff).

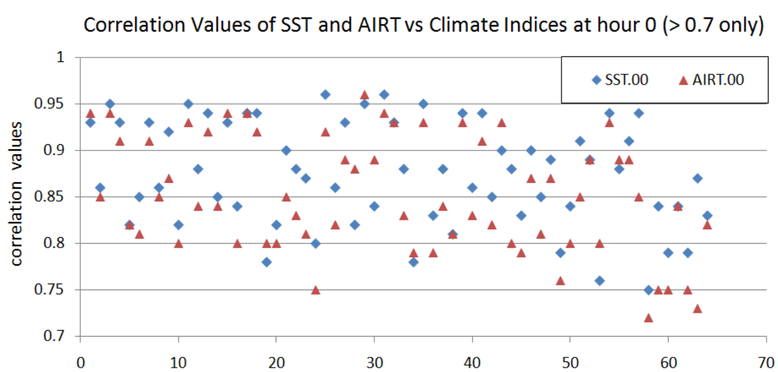
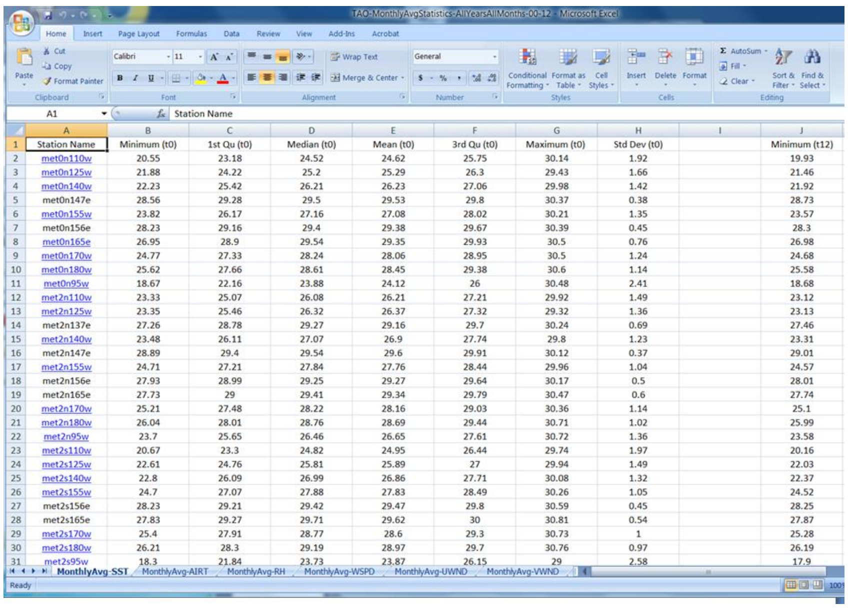


Figure 6. Comparison of 00 UTC SST and air temperature correlations for the 63 cases when r>+0.7. On average, $(\overline{r_{SST}} - \overline{r_{Tair}})$=0.02, indicating that SST has 2% higher correlation on average than air temperature. $r_{SST} > r_{air}$ in 54 of the 64 cases. 12 UTC gives similar results (not shown).

2) Excel spreadsheet of each buoy's lifetime minimum, 1st quartile, median, mean, 3rd quartile, maximum, and standard deviation, based on monthly averages of SST, air temperature, relative humidity, wind speed, zonal wind component, and meridional wind component (Fig. 7). A similar spreadsheet for monthly statistics for the entire buoy lifetime was requested by NDBC on 6/28/13. This spreadsheet contains similar metrics, but NDBC requested the removal of outliers before computing the statistics. The outliers are identified as data outside 1.5 times the interquartile range. Each monthly statistical spreadsheet contains two sets of calculations: all data included (for reference), and data minus outliers.

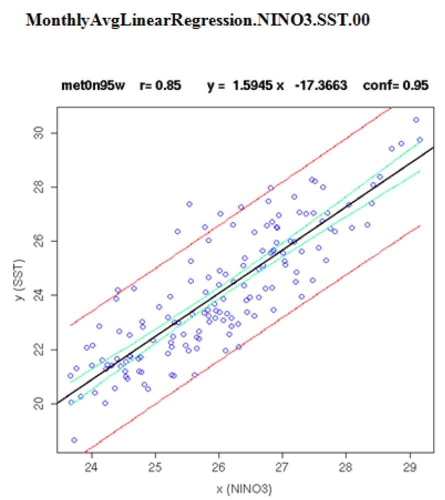


Station Name	Minimum (t0)	1st Qu (t0)	Median (t0)	Mean (t0)	3rd Qu (t0)	Maximum (t0)	Std Dev (t0)		Minimum (t12)
met0n110w	20.55	23.18	24.52	24.62	25.75	30.14	1.92		19.93
met0n125w	21.88	24.22	25.2	25.29	26.3	29.43	1.66		21.46
met0n140w	22.23	25.42	26.21	26.23	27.06	29.98	1.42		21.92
met0n147e	28.56	29.28	29.5	29.53	29.8	30.37	0.38		28.73
met0n155w	23.82	26.17	27.16	27.08	28.02	30.21	1.35		23.57
met0n156e	28.23	29.16	29.4	29.38	29.67	30.39	0.45		28.3
met0n165e	26.95	28.9	29.54	29.35	29.93	30.5	0.76		26.98
met0n170w	24.77	27.33	28.24	28.06	28.95	30.5	1.24		24.68
met0n180w	25.62	27.66	28.61	28.45	29.38	30.6	1.14		25.58
met0n95w	18.67	22.16	23.88	24.12	26	30.48	2.41		18.68
met2n110w	23.33	25.07	26.08	26.21	27.21	29.92	1.49		23.12
met2n125w	23.35	25.46	26.32	26.37	27.32	29.32	1.36		23.13
met2n137e	27.26	28.78	29.27	29.16	29.7	30.24	0.69		27.46
met2n140w	23.48	26.11	27.07	26.9	27.74	29.8	1.23		23.31
met2n147e	28.89	29.4	29.54	29.6	29.91	30.12	0.37		29.01
met2n155w	24.71	27.21	27.84	27.76	28.44	29.96	1.04		24.57
met2n156e	27.93	28.99	29.25	29.27	29.64	30.17	0.5		28.01
met2n165e	27.73	29	29.41	29.34	29.79	30.47	0.6		27.74
met2n170w	25.21	27.48	28.22	28.16	29.03	30.36	1.14		25.1
met2n180w	26.04	28.01	28.76	28.69	29.44	30.71	1.02		25.99
met2n95w	23.7	25.65	26.46	26.65	27.61	30.72	1.36		23.58
met2s110w	20.67	23.3	24.82	24.95	26.44	29.74	1.97		20.16
met2s125w	22.61	24.76	25.81	25.89	27	29.94	1.49		22.03
met2s140w	22.8	26.09	26.99	26.86	27.71	30.08	1.32		22.37
met2s155w	24.7	27.07	27.88	27.83	28.49	30.26	1.05		24.52
met2s156e	28.23	29.21	29.42	29.47	29.8	30.59	0.45		28.25
met2s165e	27.83	29.27	29.71	29.62	30	30.81	0.54		27.87
met2s170w	25.4	27.91	28.77	28.6	29.3	30.73	1		25.28
met2s180w	26.21	28.3	29.19	28.97	29.7	30.76	0.97		26.19
met2s95w	18.3	21.84	23.73	23.87	26.15	29	2.58		17.9

Figure 7. Portion of spreadsheet showing statistical metrics for the lifetime of the each buoy, based on monthly averages. Spreadsheet tabs exist for SST, air temperature, wind speed, zonal wind, and meridional wind. Statistical metrics include minimum, 1st quartile, median, mean, 3rd quartile, maximum, and standard deviation. Columns B through H are for 00 UTC, while columns J through P are for 12 UTC (cutoff in figure). Each station is listed in Column A, and if it's highlighted in blue, the station has at least one moderate to strong correlation to a climate index (when r>|±0.7|) with the surface variable. Clicking on these highlighted names will open a PowerPoint with correlation metrics, discussed in Figure 8.

3) In the lifetime statistical metric spreadsheet (#2 above), if a buoy with at least 20 data points has one instance of a correlation in which r>|±0.7| with a climate index, the spreadsheet contains a highlighted link to a PowerPoint in the buoy's corresponding subdirectory (Fig. 8). Each correlation PowerPoint shows a scatterplot of the surface value (y axis) versus the climate index (x axis), a regression line, confidence intervals and prediction intervals at the 95% level, the regression equation. The PowerPoint also shows a table of a range of climate index values versus the fitted surface value, and the

prediction interval values. The goal of the table is to provide quality control guidance for ENSO-related values depending on the phase of El Niño.



x (NINO3)	fitted y (SST)	Lower Prediction	Upper Prediction
22.6	18.66837	16.11382	21.22291
22.8	18.98726	16.43922	21.53530
23.0	19.30615	16.76424	21.84806
23.2	19.62504	17.08888	22.16120
23.4	19.94393	17.41314	22.47472
23.6	20.26282	17.73702	22.78862
23.8	20.58171	18.06051	23.10292
24.0	20.90060	18.38361	23.41760
24.2	21.21949	18.70632	23.73267
24.4	21.53839	19.02863	24.04814
24.6	21.85728	19.35056	24.36400
24.8	22.17617	19.67208	24.68025
25.0	22.49506	19.99321	24.99690
25.2	22.81395	20.31395	25.31396
25.4	23.13284	20.63428	25.63140
25.6	23.45173	20.95421	25.94925
25.8	23.77062	21.27375	26.26750
26.0	24.08951	21.59288	26.58615
26.2	24.40841	21.91161	26.90520
26.4	24.72730	22.22994	27.22465
26.6	25.04619	22.54787	27.54450
26.8	25.36508	22.86541	27.86475
27.0	25.68397	23.18254	28.18540
27.2	26.00286	23.49927	28.50645
27.4	26.32175	23.81561	28.82789
27.6	26.64064	24.13155	29.14973
27.8	26.95954	24.44710	29.47197
28.0	27.27843	24.76225	29.79460
28.2	27.59732	25.07702	30.11762
28.4	27.91621	25.39139	30.44103
28.6	28.23510	25.70538	30.76482
28.8	28.55399	26.01898	31.08900
29.0	28.87288	26.33220	31.41357
29.2	29.19177	26.64504	31.73851

Figure 8. Example of a PowerPoint image initiated by clicking on “met0n95w” in Row 11 in Fig. 7. This shows all correlations in which r>|±0.7|. In this case, the equatorial buoy located at 95°W has a correlation coefficient of 0.85 between SST and the Niño 3 region at 00 UTC. The corresponding linear regression equation is *SST=1.5945 Niño 3-17.3663*. The green line on the scatterplot on the left shows the confidence interval at the 95% confidence level. The red lines indicate the prediction level. A table showing the database range of Niño 3 values is shown in the first column, the linear regression computed value of SST in column 2, and the confidence level range in columns 3 and 4. These 4 columns can provide quality control guidance if an observation is highly correlated to ENSO patterns. In this example, SST at 12 UTC also possessed strong correlations to Niño 3, and was contained in Slide 2 of the PowerPoint (not shown). Some buoys can be moderately to highly correlated to multiple climate indices or regions, such as the buoy at 2°N and 170°W in which SST is correlated to ONI, Niño 3, and Niño 3.4 (not shown).

In individual buoy subdirectories (all plots are done for 00 UTC and 12 UTC), each PowerPoint contains (Fig. 9):

1) Scatterplot of daily values versus year (x axis) for each month.
2) Histogram frequency bin of each daily value versus magnitude (x axis) for lifetime of buoy, partitioned by month.

3) Box and Stem plots of daily values versus year (x axis) for each month.
4) Scatterplot of mean monthly values versus year (x axis) for each month.
5) Scatterplot of mean monthly values versus year (x axis) for each month, overlapped with the climate index SOI, TNI, or local Niño region.

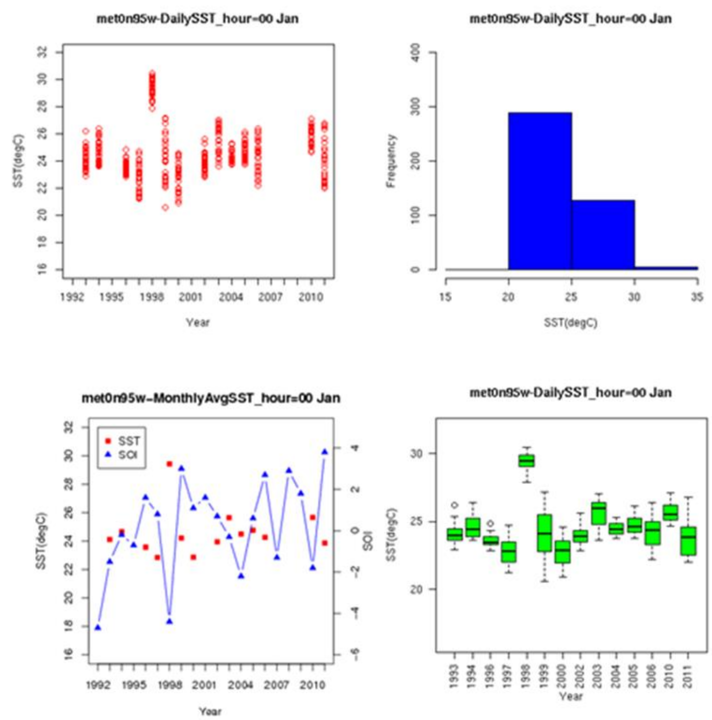


Figure 9. Examples of different types of monthly surface analysis plots for the equatorial buoy located at 95°W, all valid for 00 UTC SST data in January. Top left: Scatterplot for daily value on y axis and year on the x axis. Bottom left: Scatterplot of monthly averages of the data in the top left, superimposed with a trend line for a climate index (in this case, the Southern Oscillation Index, or SOI). Top right: histogram of frequency tallies versus SST. Bottom right: same dataset as in top left, but a box and whisker plot. Note how SOI and monthly mean SST are somewhat inversely correlated, but as will be seen, the correlation is a modest -0.26 (Fig. 10).

In individual buoy subdirectories (all plots are done for 00 UTC and 12 UTC), each PowerPoint also contains a correlation matrix for each climate index SOI, TNI, or local Niño region, using R routine SPLOM (scatterplot of matrices), consisting of (Fig. 10):

1) Scatterplots in lower left of matrix for all pairs of datasets, with a regression line and correlation ellipse. In general, the narrower the ellipse, the stronger the relationship. The ellipse is scaled as $\sqrt{1+r}$ and $\sqrt{1-r}$.

2) Histogram of relationship along the matrix diagonal, with a curve to qualitatively ascertain if the association is Gaussian.
3) Correlation coefficients of all pairs in upper right of matrix.

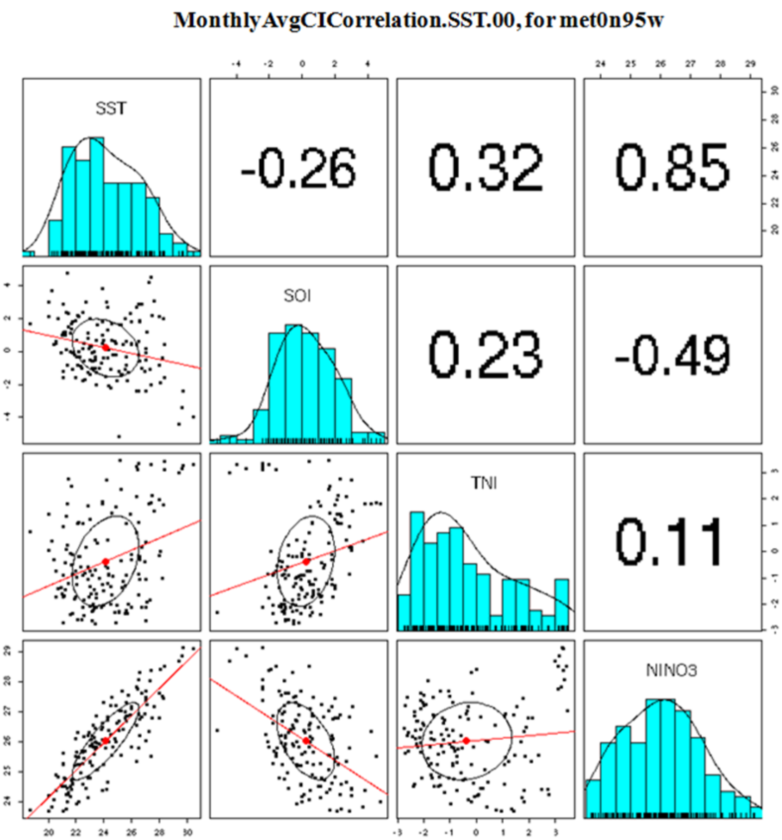


Figure 10. Correlation matrix for the equatorial buoy located at 95°W, valid for 00 UTC monthly averaged SST data. Scatterplots are shown in lower left of matrix for all pairs of datasets, and include a regression line and correlation ellipse. In general, the narrower the ellipse, the stronger is the relationship. Histograms of the relationship are shown along the matrix diagonal, with a curve to qualitatively ascertain if the association is Gaussian. The correlation coefficient of all pairs is shown in the upper right of the matrix. When available, overlapping Niño regions and/or ONI will also be shown in other columns.

Milestone D: S*ub surface water temperature* (58 buoys), and *sub surface salinity* (60 buoys)

In general, these products are the same as the surface plots. A spreadsheet example for sub surface water temperature is shown in Fig. 11.

	A	B	C	D	E	F	G	H	I	J
1	Station Name	Minimum (t0)	1st Qu (t0)	Median (t0)	Mean (t0)	3rd Qu (t0)	Maximum (t0)	Std Dev (t0)		Minimum (t12)
2	t0n110w_1m	20.55	23.14	24.48	24.57	25.79	30.14	1.95		19.93
3	t0n110w_5m	21.06	23.36	24.4	24.53	25.57	29.37	1.71		20.81
4	t0n110w_8m	21.67	22.24	23.8	23.84	24.9	27.14	2.03		21.51
5	t0n110w_10m	19.87	22.72	24.05	24.08	25.34	29.22	1.97		19.91
6	t0n110w_13m	21.32	22.94	24.18	24.03	25.35	27.29	1.62		21.22
7	t0n110w_20m	17.72	21.6	23.22	22.87	24.09	27.04	1.93		17.7
8	t0n110w_25m	16.04	21.49	23.06	23.02	24.31	28.8	2.34		16
9	t0n110w_28m	19.72	21.37	23.08	23.08	24.25	26.62	1.96		19.82
10	t0n110w_35m	19.74	20.76	23.42	22.99	24.35	26.67	2.18		19.98
11	t0n110w_40m	14.64	18.85	20.7	20.41	22.12	25.51	2.58		14.62
12	t0n110w_45m	16.42	19.82	21.43	21.57	23.28	28.31	2.48		16.21
13	t0n110w_48m	16.16	18.74	21.1	20.9	22.98	25.06	2.61		15.95
14	t0n110w_60m	13.76	17.18	19.01	19.39	21.23	28.15	2.94		13.71
15	t0n110w_80m	13.32	15.58	16.6	17.42	18.81	28.09	2.73		13.33
16	t0n110w_83m	14.58	15.48	16.94	17.05	17.69	22.24	2.1		14.7
17	t0n110w_100m	13.08	14.58	15.33	15.9	16.34	27.56	2.21		13.1
18	t0n110w_120m	12.99	13.92	14.41	14.83	15.04	25.06	1.57		12.99
19	t0n110w_123m	13.7	14.2	14.59	14.9	15.44	17.93	1.05		13.69
20	t0n110w_140m	12.9	13.52	13.86	14.07	14.25	19.98	0.91		12.89
21	t0n110w_160m	12.84	13.22	13.53	13.52	13.76	14.69	0.43		12.83
22	t0n110w_180m	12.63	12.99	13.13	13.16	13.3	14.03	0.26		12.62
23	t0n110w_200m	12.43	12.78	12.92	13	13.16	14.25	0.34		12.43
24	t0n110w_250m	12.15	12.43	12.56	12.59	12.73	12.97	0.22		12.2
25	t0n110w_300m	10.56	11.63	11.84	11.83	12.08	12.78	0.4		10.56
26	t0n110w_500m	7.23	8	8.16	8.16	8.3	8.85	0.25		7.11
27	t0n125w_1m	21.88	23.93	25.23	25.29	26.36	29.43	1.76		21.46
28	t0n125w_10m	23.19	24.61	25.16	25	25.61	26.21	0.87		22.91
29	t0n125w_13m	22.98	24.48	25.08	24.88	25.51	26.16	0.92		22.65
30	t0n125w_20m	19.67	23.04	24.39	23.96	25.17	26.84	1.65		19.67
31	t0n125w_40m	17.6	21.12	22.7	22.52	24.22	26.43	2.09		17.78

Figure 11. As in Figure 7, but for all subsurface levels of water temperature.

Milestone E: *Spatial correlation patterns when* r>|±0.7|

Spatial plots of surface wind, temperature, and SST where r>|±0.7| are shown in the TAO/TRITON region (Figs. 12 and 13). In addition, spatial plots for sub surface water temperature depths reached for r>|±0.7| are displayed (Fig. 14-16). Low sample numbers were removed from this analysis.

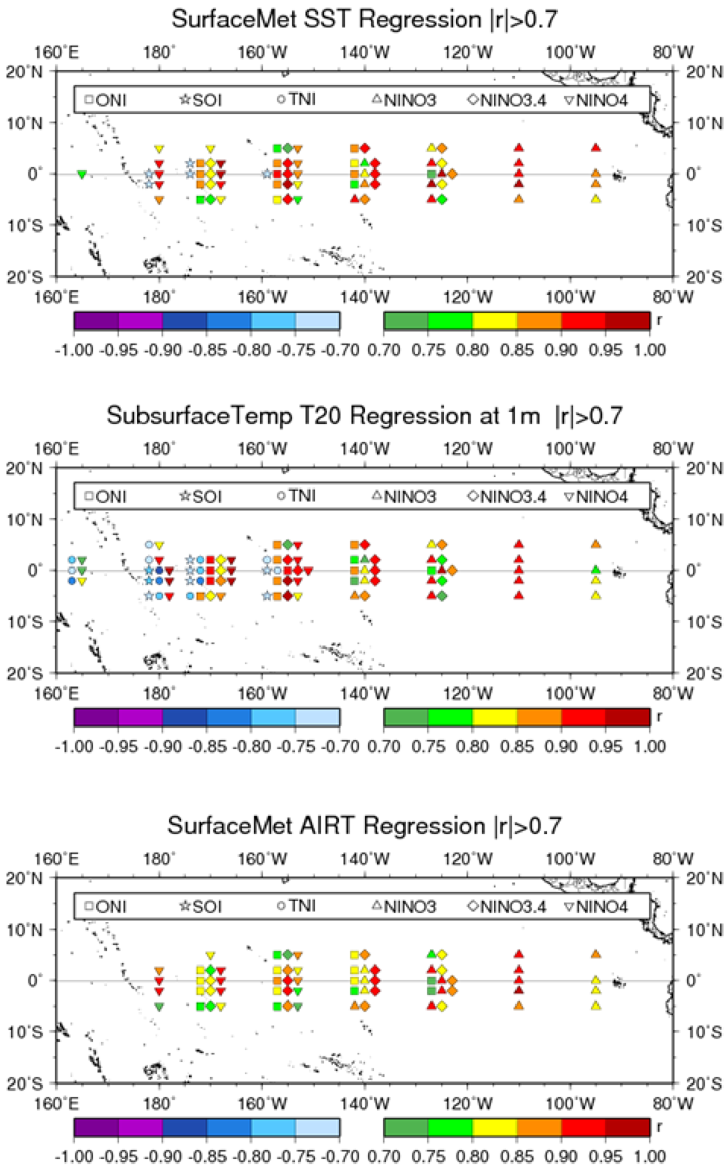


Figure 12. All buoys in which the correlation are r>|±0.7|, color-coded for ONI, SOI, TNI, Niño 3, Niño 3.4, and Niño 4 for surface water temperature (top), 1-m water temperature (middle), and surface air temperature (bottom). Side by side symbols indicate multiple climate indices are r>|±0.7|.

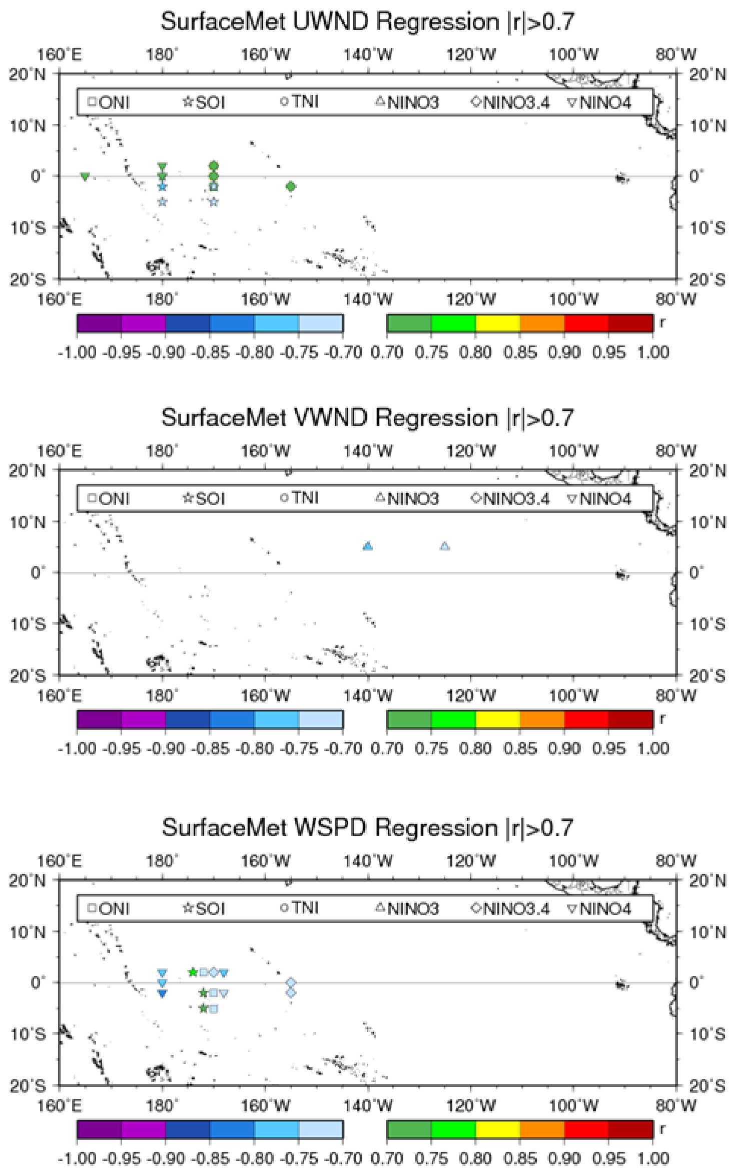


Figure 13. All buoys in which the correlation are r>|±0.7|, color-coded for ONI, SOI, TNI, Niño 3, Niño 3.4, and Niño 4 for wind parameters. Side by side symbols indicate multiple climate indices are r>|±0.7|.

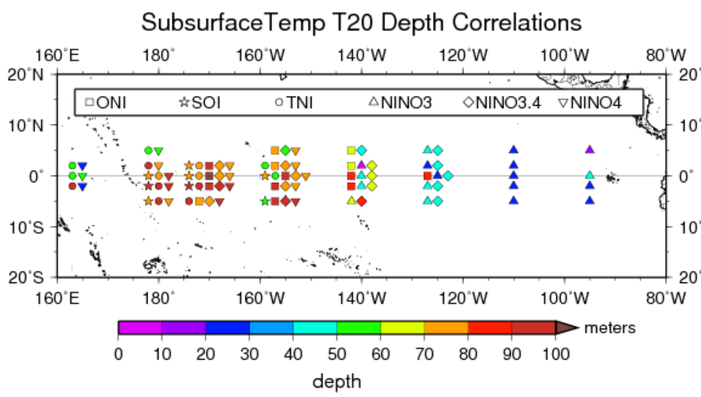


Figure 14. Color-coded depths at which the correlations reach r>|±0.7|for ONI, SOI, TNI, Niño 3, Niño 3.4, and Niño 4.

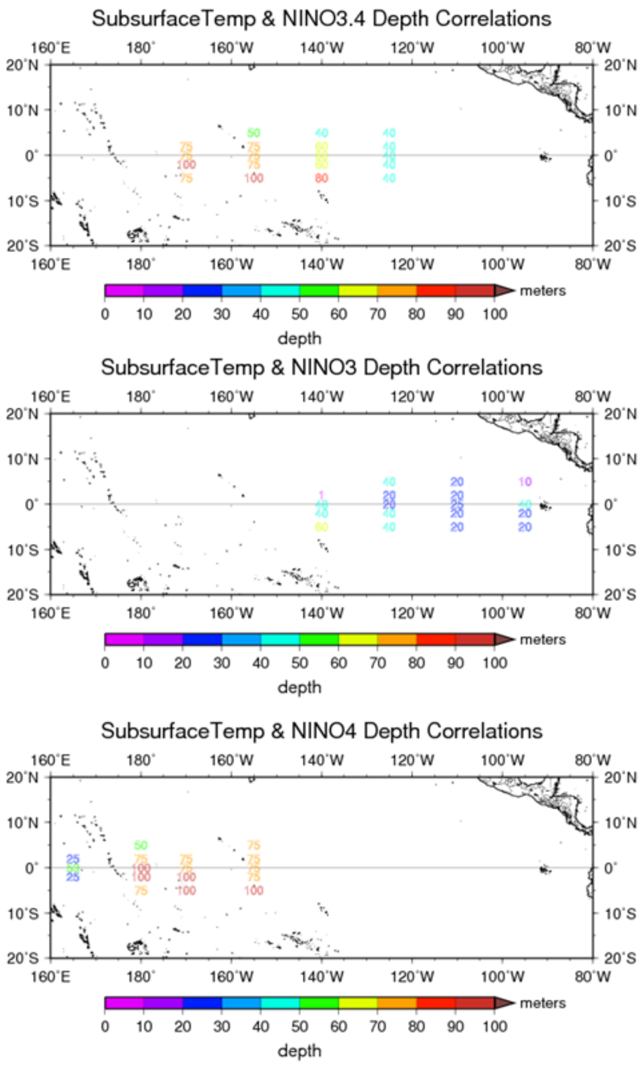


Figure 15. Color-coded depths at which the correlations reach r>|±0.7|for Niño 3, Niño 3.4, and Niño 4.

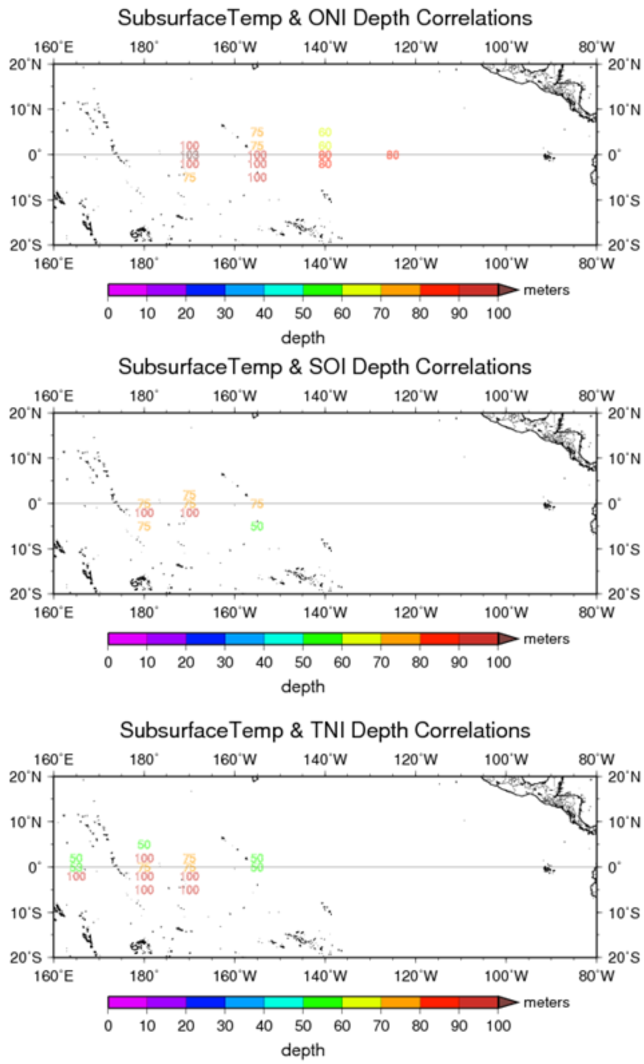


Figure 16. Color-coded depths at which the correlations reach r>|±0.7|for ONI, SOI, and TNI.

Description of significant research results, protocols developed, and research transitions

All statistical and graphical products have been delivered. These include statistics in Excel spreadsheet of each buoy's lifetime minimum for the 1st quartile, median, mean, 3rd quartile, maximum, and standard deviation, based on monthly averages of SST, air temperature, relative humidity, wind speed, zonal wind component, and meridional wind component (Fig. 7), subsurface water temperature (Fig. 11), and salinity. A similar spreadsheet for monthly statistics for the entire buoy lifetime was also provided, with outliers removed before computing the statistics. The outliers are identified as data outside 1.5 times the interquartile range. These monthly metrics are of the most interest to NDBC for their quality control algorithms.

In addition, ENSO correlation products have also been provided with regression equations and predictor intervals for better QC guidance, using r>|±0.7| as a threshold. The ENSO signal is strongest for SST followed closely by air temperature. On average, ($\overline{r_{SST}} - \overline{r_{Tair}}$)=0.02 for cases exceeding the r>+0.7 threshold, indicating that SST has 2% higher correlation on average than air temperature. $r_{SST} > r_{air}$ in 54 of the 64 cases at 00 UTC (Fig. 6). 12 UTC gives similar results (not shown). Since air temperature had few negative correlations, these cases are excluded from the 64 cases where r>+0.7. A list of all correlations for surface water temperature and surface air temperature with r>|±0.7| is shown in Table 1 and Table 2.

Surface air and water temperature generally correlated best with their respective Niño regions (Fig. 12, top and bottom). In addition, ONI relationships occur in the western side of the TAO domain from 170°W to 140°W for most locations, plus on the equator at 125°W. This is consistent with the ONI definition, which is related to a 3-month running mean of SST anomalies in the Niño 3.4 region (5°N-5°S, 120°W-170°W). However, ONI's correlation with SST is on average 0.08 less than the peak Niño region correlation.

One interesting finding is that the water temperature correlations show a tendency towards higher values at 1-m depth (Fig. 12, middle) than surface water temperature (Fig. 12, top). We postulate that the 1-m level is less susceptible to diurnal fluctuations and have more stable regression relationships. For example, more SOI relationships are seen at 1-meter. Furthermore, while no TNI relationships are seen at the surface, a few past the r>|±0.7| threshold at 1 m. Also noteworthy is that SOI and TNI show a negative relationship to water temperature parameters.

Most wind correlations occur in the center of the domain from 180°W to 170°W, with correlations to their respective Niño regions, SOI, or ONI (Fig. 13). The correlations are for wind speed or zonal wind, with only two meridional wind value negatively correlated to Niño 3 at 5°N in the center of the domain. It is likely that physical relationships regarding ongoing ENSO events with these wind variables exist, and should be explored in follow-up research. Niño 4 and Niño 3.4 are positive correlated with westerly winds, while SOI is negatively correlated with westerly winds in the tropical Southern Hemisphere. ONI is not seen for the zonal wind component, but does exceed the r>|±0.7| threshold with a negative correlation. Niño 4 and Niño 3.4 also show a negative correlation, while SOI is a positive relationship to wind speed. No RH-ENSO relationship was noted based on the r>|±0.7| threshold except for a single buoy located at

125°W and 0°N (r=-0.72 with ONI, not shown). No TNI relationship is found with RH, wind, or salinity at the chosen threshold. A list of all correlations for surface wind with r>|±0.7| is shown in Table 3.

The ENSO signal penetrates deepest in the western domain, with a "deep-water" ONI signal on the equator extending to 125°W (Figs. 14-16). From 180°W to 140°W, the ENSO signal reaches from 40 to 100 m, with a majority of the deeper signals in the Southern Hemisphere. The ENSO correlation is shallow on the far eastern and western edge of the TAO domain. All climate metrics show deep-water relationships, with SOI containing the fewest hits. Full documentation of all the depth profile correlations is shown in Table 4.

Some ENSO correlations are seen with salinity profiles based on the r>|±0.7| threshold, but in most cases the data sample is limited so the significance of the relationship is unclear. Figure 17 shows a scatterplot example for 140°W, 0°N at 5 m. The following two buoys met the r>|±0.7| threshold with a reasonable number of depth levels: 140°W, 0°N, down to 60 m; and 165°E, 0°N, down to 50 m (Table 5). In addition, the following location showed correlations at single levels: 170°W, 0°N (only at 75 m); 125°W, 0°N (only at 120 m); 170°W, 2°N (only at 1 m); 95°W, 2°S (only at 120 m); 165°E, 2°N (only at 1 m); and 165°E, 2°S (only at 1 m).

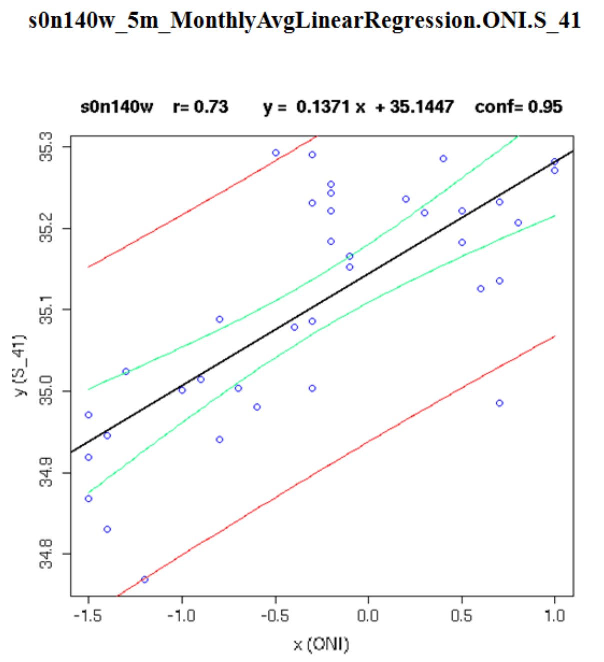


Figure 17. As in Fig. 8, but an example of a salinity correlation at 5 m of ONI for the equatorial buoy located at 140°W. Note that the sample size is smaller, though.

Formatted: Font: (Default) Calibri

Information on collaborators / partners: None reported

Information on any outreach activities:

General description: Preliminary results were presented at NDBC 12/17/12, and final results will be presented 7/16/13 at NDBC.

NOAA sponsor and NOAA office of primary technical contact: Richard Crout, NWS

Related NOAA strategic goals: Climate Adaptation and Mitigation

Related NOAA enterprise objectives: Science and Technology

Table 1. Correlations for surface water temperature at 00 and 12 UTC in instances when r >|±0.7| and their corresponding depth and climate index.

Buoy	SST-Teleconnection	r value where |r| > 0.7
MET0N110W	NINO3	+0.93 +0.92
MET0N125W	ONI	+0.72 +0.76
MET0N125W	NINO3	+0.95 +0.93
MET0N125W	NINO3.4	+0.86 +0.88
MET0N140W	ONI	+0.85 +0.85
MET0N140W	NINO3	+0.82 +0.8
MET0N140W	NINO3.4	+0.93 +0.92
MET0N155W	SOI	-0.73 -0.73
MET0N155W	ONI	+0.92 +0.92
MET0N155W	NINO3.4	+0.93 +0.93
MET0N155W	NINO4	+0.86 +0.86
MET0N165E	NINO4	+0.75 +0.74
MET0N170W	SOI	-0.72 -0.72
MET0N170W	ONI	+0.88 +0.88
MET0N170W	NINO3.4	+0.82 +0.81
MET0N170W	NINO4	+0.95 +0.94
MET0N180W	SOI	-0.72 -0.72
MET0N180W	NINO4	+0.94 +0.94
MET0N95W	NINO3	+0.85 +0.86
MET2N110W	NINO3	+0.93 +0.93
MET2N125W	NINO3	+0.94 +0.93
MET2N125W	NINO3.4	+0.84 +0.87
MET2N140W	ONI	+0.82 +0.83
MET2N140W	NINO3	+0.78 +0.76
MET2N140W	NINO3.4	+0.94 +0.94
MET2N155W	ONI	+0.87 +0.88
MET2N155W	NINO3.4	+0.9 +0.9
MET2N155W	NINO4	+0.88 +0.88

MET2N170W	SOI	-0.74 -0.73
MET2N170W	ONI	+0.86 +0.86
MET2N170W	NINO3.4	+0.8 +0.8
MET2N170W	NINO4	+0.96 +0.96
MET2N180W	NINO4	+0.93 +0.93
MET2N95W	NIINO3	+0.82 +0.82
MET2S110W	NINO3	+0.95 +0.96
MET2S125W	NINO3	+0.96 +0.95
MET2S125W	NINO3.4	+0.84 +0.87
MET2S140W	ONI	+0.78 +0.79
MET2S140W	NINO3	+0.88 +0.86
MET2S140W	NINO3.4	+0.93 +0.93
MET2S155W	ONI	+0.88 +0.87
MET2S155W	NINO3.4	+0.95 +0.95
MET2S155W	NINO4	+0.83 +0.82
MET2S170W	ONI	+0.86 +0.86
MET2S170W	NINO3.4	+0.81 +0.82
MET2S170W	NINO4	+0.94 +0.94
MET2S180W	SOI	-0.72 -0.73
MET2S180W	NINO4	+0.94 +0.94
MET2S95W	NINO3	+0.85 +0.87
MET5N110W	NINO3	+0.9 +0.88
MET5N125W	NINO3	+0.83 +0.81
MET5N125W	NINO3.4	+0.88 +0.89
MET5N140W	ONI	+0.85 +0.86
MET5N140W	NINO3.4	+0.9 +0.9
MET5N155W	ONI	+0.79 +0.8
MET5N155W	NINO3.4	+0.71
MET5N155W	NINO4	+0.89 +0.9
MET5N170W	NINO4	+0.84 +0.84
MET5N180W	NINO4	+0.8 +0.8
MET5N95W	NINO3	+0.91 +0.89
MET5S110W	NINO3	+0.89 +0.9
MET5S125W	NINO3	+0.94 +0.94
MET5S125W	NINO3.4	+0.76 +0.78
MET5S140W	NINO3	+0.91 +0.9
MET5S140W	NINO3.4	+0.88 +0.89
MET5S155W	ONI	+0.84 +0.84
MET5S155W	NINO3.4	+0.94 +0.94
MET5S155W	NINO4	+0.75 +0.75
MET5S170W	ONI	+0.79 +0.78
MET5S170W	NINO3.4	+0.79 +0.8
MET5S170W	NINO4	+0.84 +0.83
MET5S180W	NINO4	+0.87 +0.87
MET5S95W	NINO3	+0.83 +0.84

Table 2. Correlations for surface air temperature at 00 and 12 UTC in instances when r >|±0.7| and their corresponding depth and climate index.

Buoy	AIRT-Teleconnection	r value where |r| > 0.7
MET0N110W	NINO3	+0.94 +0.94
MET0N125W	ONI	+0.71
MET0N125W	NINO3	+0.94 +0.93
MET0N125W	NINO3.4	+0.85 +0.87
MET0N140W	ONI	+0.81 +0.82
MET0N140W	NINO3	+0.82 +0.81
MET0N140W	NINO3.4	+0.91 +0.91
MET0N155W	ONI	+0.87 +0.87
MET0N155W	NINO3.4	+0.91 +0.91
MET0N155W	NINO4	+0.85 +0.85
MET0N170W	ONI	+0.84 +0.84
MET0N170W	NINO3.4	+0.8 +0.79
MET0N170W	NINO4	+0.93 +0.93
MET0N180W	NINO4	+0.92 +0.92
MET0N95W	NINO3	+0.84 +0.86
MET2N110W	NINO3	+0.94 +0.94
MET2N125W	NINO3	+0.94 +0.93
MET2N125W	NINO3.4	+0.8 +0.81
MET2N140W	ONI	+0.8 +0.81
MET2N140W	NINO3	+0.8 +0.8
MET2N140W	NINO3.4	+0.92 +0.92
MET2N155W	ONI	+0.81 +0.82
MET2N155W	NINO3.4	+0.85 +0.86
MET2N155W	NINO4	+0.83 +0.85
MET2N170W	ONI	+0.82 +0.83
MET2N170W	NINO3.4	+0.75 +0.76
MET2N170W	NINO4	+0.92 +0.92
MET2N180W	NINO4	+0.89 +0.88
MET2N95W	NIINO3	+0.88 +0.88
MET2S110W	NINO3	+0.96 +0.97
MET2S125W	ONI	+0.71 +0.72
MET2S125W	NINO3	+0.94 +0.94
MET2S125W	NINO3.4	+0.89 +0.89
MET2S140W	ONI	+0.79 +0.8
MET2S140W	NINO3	+0.83 +0.83
MET2S140W	NINO3.4	+0.93 +0.93
MET2S155W	ONI	+0.84 +0.85
MET2S155W	NINO3.4	+0.93 +0.93
MET2S155W	NINO4	+0.79 +0.78
MET2S170W	ONI	+0.83 +0.83
MET2S170W	NINO3.4	+0.81 +0.81
MET2S170W	NINO4	+0.93 +0.93
MET2S180W	NINO4	+0.91 +0.92

MET2S95W	NINO3	+0.82 +0.84
MET5N110W	NINO3	+0.93 +0.94
MET5N125W	NINO3	+0.79 +0.78
MET5N125W	NINO3.4	+0.8 +0.8
MET5N140W	ONI	+0.81 +0.83
MET5N140W	NINO3.4	+0.87 +0.88
MET5N155W	ONI	+0.76 +0.8
MET5N155W	NINO3.4	+0.72 +0.77
MET5N155W	NINO4	+0.87 +0.88
MET5N170W	NINO4	+0.8 +0.78
MET5N95W	NINO3	+0.85 +0.84
MET5S110W	NINO3	+0.89 +0.89
MET5S125W	NINO3	+0.93 +0.93
MET5S125W	NINO3.4	+0.8 +0.8
MET5S140W	NINO3	+0.89 +0.9
MET5S140W	NINO3.4	+0.89 +0.89
MET5S155W	ONI	+0.75 +0.73
MET5S155W	NINO3.4	+0.85 +0.85
MET5S155W	NINO4	+0.72
MET5S170W	ONI	+0.75 +0.76
MET5S170W	NINO3.4	+0.75 +0.77
MET5S170W	NINO4	+0.84 +0.88
MET5S180W	NINO4	+0.73 +0.71
MET5S95W	NINO3	+0.82 +0.83

Table 3. Correlations for winds at 00 and 12 UTC in instances when r >|±0.7| and their corresponding depth and climate index.

Buoy	Var	Wind-Teleconnection	r value where |r| > 0.7
MET0N155W	spd	NINO3.4	-0.71
MET0N165E	u	NINO4	+0.73 +0.75
MET0N170W	u	ONI	+0.8 +0.79
MET0N170W	u	NINO3.4	+0.74 +0.74
MET0N180W	spd	NINO4	-0.78 -0.77
MET0N180W	u	SOI	-0.73 -0.73
MET0N180W	u	NINO4	+0.74 +0.72
MET2N137E	u	TNI	-0.74 -0.74 Small sample
MET2N137E	v	SOI	+0.89 small sample
MET2N170W	spd	SOI	+0.75 +0.73
MET2N170W	spd	ONI	-0.74 -0.74
MET2N170W	spd	NINO3.4	-0.73 -0.73
MET2N170W	spd	NINO4	-0.77 -0.77
MET2N170W	u	ONI	+0.8 +0.79
MET2N170W	u	NINO3.4	+0.73 +0.73
MET2N180W	spd	NINO4	-0.78 -0.76
MET2N180W	u	NINO4	+0.74 +0.72
MET2S155W	spd	NINO3.4	-0.75 -0.77

MET2S155W	u	NINO3.4	+0.71 +0.72
MET2S170W	spd	SOI	+0.72
MET2S170W	spd	ONI	-0.71 -0.72
MET2S170W	spd	NINO4	-0.71
MET2S170W	u	SOI	-0.72 -0.72
MET2S170W	u	ONI	+0.73 +0.72
MET2S180W	spd	NINO4	-0.81 -0.79
MET2S180W	u	SOI	-0.77 -0.77
MET5N125W	v	NINO3	-0.72 -0.71
MET5N140W	v	NINO3	-0.76 -0.75
MET5S170W	spd	SOI	+0.71
MET5S170W	spd	ONI	-0.71
MET5S170W	u	SOI	-0.71
MET5S180W	u	SOI	-0.72 -0.71

Table 4. Correlations for water temperature at 00 and 12 UTC in instances when r >|±0.7| and their corresponding depth and climate index.

Buoy	depth	T_20-Teleconnection	r value where r >|±0.7|
T0N110W	1m	NINO3	+0.92 +0.93
T0N110W	5m	NINO3	+0.89 +0.89
T0N110W	10m	NINO3	+0.89 +0.9
T0N110W	13m	NINO3	+0.77 +0.77
T0N110W	20m	NINO3	+0.76 +0.76
T0N110W	25m	NINO3	+0.78 +0.78
T0N125W	1m	ONI	+0.76 +0.79
T0N125W	1m	NINO3	+0.95 +0.93
T0N125W	1m	NINO3.4	+0.88 +0.9
T0N125W	20m	ONI	+0.74 +0.74
T0N125W	20m	NINO3	+0.73 +0.74
T0N125W	20m	NINO3.4	+0.84 +0.84
T0N125W	40m	NINO3.4	+0.71
T0N125W	60m	ONI	+0.75 +0.75
T0N125W	80m	ONI	+0.76 +0.76
T0N125W	140m	ONI	+0.71
T0N140W	1m	ONI	+0.85 +0.86
T0N140W	1m	NINO3	+0.84 +0.82
T0N140W	1m	NINO3.4	+0.93 +0.93
T0N140W	5m	ONI	+0.86 +0.86
T0N140W	5m	NINO3	+0.79 +0.79
T0N140W	5m	NINO3.4	+0.92 +0.92
T0N140W	10m	ONI	+0.88 +0.88
T0N140W	10m	NINO3	+0.81 +0.81
T0N140W	10m	NINO3.4	+0.92 +0.93
T0N140W	13m	SOI	-0.73 -0.73
T0N140W	13m	ONI	+0.85 +0.84

T0N140W	13m	NINO3	+0.75 +0.77
T0N140W	13m	NINO3.4	+0.91 +0.92
T0N140W	20m	ONI	+0.81 +0.81
T0N140W	20m	NINO3	+0.73 +0.74
T0N140W	20m	NINO3.4	+0.92 +0.93
T0N140W	25m	ONI	+0.87 +0.87
T0N140W	25m	NINO3	+0.76 +0.76
T0N140W	25m	NINO3.4	+0.9 +0.9
T0N140W	28m	ONI	+0.71 +0.74
T0N140W	28m	NINO3	+0.71 +0.71
T0N140W	28m	NINO3.4	+0.86 +0.9
T0N140W	40m	ONI	+0.82 +0.83
T0N140W	40m	NINO3.4	+0.89 +0.9
T0N140W	45m	ONI	+0.82 +0.82
T0N140W	45m	NINO3.4	+0.8 +0.8
T0N140W	48m	ONI	+0.83 +0.83
T0N140W	48m	NINO3	+0.73 +0.72
T0N140W	48m	NINO3.4	+0.85 +0.85
T0N140W	60m	ONI	+0.84 +0.83
T0N140W	60m	NINO3.4	+0.8 +0.79
T0N140W	80m	ONI	+0.72 +0.71
T0N155W	1m	SOI	-0.71 -0.71
T0N155W	1m	TNI	-0.72 -0.72
T0N155W	1m	ONI	+0.91 +0.91
T0N155W	1m	NINO3.4	+0.94 +0.93
T0N155W	1m	NINO4	+0.91 +0.91
T0N155W	25m	SOI	-0.71 -0.71
T0N155W	25m	TNI	-0.73 -0.73
T0N155W	25m	ONI	+0.91 +0.91
T0N155W	25m	NINO3.4	+0.92 +0.92
T0N155W	25m	NINO4	+0.92 +0.92
T0N155W	50m	SOI	-0.73 -0.73
T0N155W	50m	TNI	-0.74 -0.74
T0N155W	50m	ONI	+0.92 +0.92
T0N155W	50m	NINO3.4	+0.89 +0.89
T0N155W	50m	NINO4	+0.91 +0.91
T0N155W	75m	SOI	-0.71 -0.71
T0N155W	75m	ONI	+0.86 +0.86
T0N155W	75m	NINO3.4	+0.77 +0.77
T0N155W	75m	NINO4	+0.82 +0.82
T0N155W	100m	ONI	+0.71 +0.71
T0N165E	1m	TNI	-0.73 -0.74
T0N165E	1m	NINO4	+0.74 +0.74
T0N165E	3m	TNI	-0.75 -0.71
T0N165E	5m	TNI	-0.72 -0.73
T0N165E	10m	TNI	-0.74 -0.74

T0N165E	10m	NINO4	0.72 0.71
T0N165E	13m	SOI	-0.77 -0.77
T0N165E	13m	TNI	-0.82 -0.82
T0N165E	13m	NINO4	+0.86 +0.86
T0N165E	25m	TNI	-0.86 -0.86
T0N165E	25m	NINO4	+0.86 +0.86
T0N165E	30m	TNI	-0.75 -0.75
T0N165E	50m	TNI	-0.73 -0.73
T0N165E	53m	TNI	-0.75 -0.75
T0N165E	53m	NINO4	+0.76 +0.76
T0N165E	203m	NINO4	-0.74 ??
T0N170W	1m	SOI	-0.75 -0.75
T0N170W	1m	TNI	-0.79 -0.79
T0N170W	1m	ONI	+0.93 +0.94
T0N170W	1m	NINO3.4	+0.84 +0.84
T0N170W	1m	NINO4	+0.96 +0.96
T0N170W	5m	SOI	-0.84 -0.84
T0N170W	5m	TNI	-0.77 -0.76
T0N170W	5m	ONI	+0.95 +0.96
T0N170W	5m	NINO3.4	+0.91 +0.91
T0N170W	5m	NINO4	+0.97 +0.97
T0N170W	10m	SOI	-0.75 -0.75
T0N170W	10m	TNI	-0.81 -0.8
T0N170W	10m	ONI	+0.94 +0.94
T0N170W	10m	NINO3.4	+0.83 +0.84
T0N170W	10m	NINO4	+0.95 +0.95
T0N170W	13m	SOI	-0.82 -0.82
T0N170W	13m	TNI	-0.73 -0.73
T0N170W	13m	ONI	+0.95 +0.95
T0N170W	13m	NINO3.4	+0.9 +0.9
T0N170W	13m	NINO4	+0.96 +0.96
T0N170W	25m	SOI	-0.74 -0.74
T0N170W	25m	TNI	-0.79 -0.79
T0N170W	25m	ONI	+0.93 +0.93
T0N170W	25m	NINO3.4	+0.83 +0.83
T0N170W	25m	NINO4	+0.95 +0.95
T0N170W	50m	SOI	-0.75 -0.75
T0N170W	50m	TNI	-0.81 -0.81
T0N170W	50m	ONI	+0.94 +0.94
T0N170W	50m	NINO3.4	+0.82 +0.81
T0N170W	50m	NINO4	+0.94 +0.94
T0N170W	53m	SOI	-0.81 -0.82
T0N170W	53m	TNI	-0.75 -0.75
T0N170W	53m	ONI	+0.95 +0.95
T0N170W	53m	NINO3.4	+0.87 +0.87
T0N170W	53m	NINO4	+0.96 +0.96

T0N170W	75m	SOI	-0.75 -0.75
T0N170W	75m	TNI	-0.75 -0.74
T0N170W	75m	ONI	+0.91 +0.92
T0N170W	75m	NINO3.4	+0.76 +0.76
T0N170W	75m	NINO4	+0.89 +0.89
T0N170W	100m	ONI	+0.77 +0.77
T0N170W	103m	ONI	+0.71
T0N180W	1m	SOI	-0.78 -0.79
T0N180W	1m	TNI	-0.88 -0.87
T0N180W	1m	NINO4	+0.97 +0.97
T0N180W	25m	SOI	-0.76 -0.75
T0N180W	25m	TNI	-0.89 -0.89
T0N180W	25m	NINO4	+0.96 +0.96
T0N180W	50m	SOI	-0.76 -0.76
T0N180W	50m	TNI	-0.89 -0.89
T0N180W	50m	NINO4	+0.95 +0.95
T0N180W	75m	SOI	-0.76 -0.76
T0N180W	75m	TNI	-0.87 -0.87
T0N180W	75m	NINO4	+0.93 +0.93
T0N180W	100m	TNI	-0.71
T0N180W	100m	NINO4	+0.75 +0.75
T0N95W	1m	NINO3	+0.79 +0.8
T0N95W	5m	NINO3	+0.84 +0.83
T0N95W	20m	NINO3	+0.82 +0.82
T0N95W	40m	NINO3	+0.71 +0.72
T2N110W	1m	NINO3	+0.91 +0.91
T2N110W	20m	NINO3	+0.77 +0.77
T2N125W	1m	NINO3	+0.94 +0.92
T2N125W	1m	NINO3.4	+0.78 +0.83
T2N125W	20m	NINO3	+0.88 +0.89
T2N125W	20m	NINO3.4	+0.86 +0.86
T2N125W	40m	ONI	+0.71 +0.71
T2N125W	40m	NINO3.4	+0.76 +0.76
T2N125W	60m	ONI	+0.73 +0.73
T2N140W	1m	ONI	+0.79 +0.8
T2N140W	1m	NINO3	+0.72
T2N140W	1m	NINO3.4	+0.93 +0.93
T2N140W	10m	NINO3.4	+0.95 +0.95
T2N140W	13m	NINO3.4	+0.92 +0.92
T2N140W	20m	ONI	+0.77 +0.77
T2N140W	20m	NINO3.4	+0.91 +0.91
T2N140W	40m	ONI	+0.8 +0.8
T2N140W	40m	NINO3.4	+0.89 +0.89
T2N140W	60m	ONI	+0.8 +0.8
T2N140W	60m	NINO3.4	+0.77 +0.76
T2N155W	1m	TNI	-0.71

T2N155W	1m	ONI	+0.88 +0.88
T2N155W	1m	NINO3.4	+0.91 +0.91
T2N155W	1m	NINO4	+0.92 +0.92
T2N155W	25m	ONI	+0.85 +0.86
T2N155W	25m	NINO3.4	+0.89 +0.89
T2N155W	25m	NINO4	+0.91 +0.91
T2N155W	50m	TNI	-0.74 -0.74
T2N155W	50m	ONI	+0.88 +0.88
T2N155W	50m	NINO3.4	+0.88 +0.88
T2N155W	50m	NINO4	+0.92 +0.93
T2N155W	75m	ONI	+0.86 +0.87
T2N155W	75m	NINO3.4	+0.75 +0.77
T2N155W	75m	NINO4	+0.85 +0.87
T2N165E	1m	TNI	-0.79 -0.78
T2N165E	1m	NINO4	+0.71 +0.71
T2N165E	25m	TNI	-0.8 -0.8
T2N165E	25m	NINO4	+0.72 +0.71
T2N165E	50m	TNI	-0.8 -0.8
T2N170W	1m	SOI	-0.72 -0.72
T2N170W	1m	TNI	-0.77 -0.77
T2N170W	1m	ONI	+0.9 +0.9
T2N170W	1m	NINO3.4	+0.81 +0.81
T2N170W	1m	NINO4	+0.96 +0.96
T2N170W	25m	SOI	-0.73 -0.73
T2N170W	25m	TNI	-0.77 -0.77
T2N170W	25m	ONI	+0.91 +0.91
T2N170W	25m	NINO3.4	+0.81 +0.81
T2N170W	25m	NINO4	+0.95 +0.95
T2N170W	50m	TNI	-0.71 -0.71
T2N170W	50m	ONI	+0.88 +0.88
T2N170W	50m	NINO3.4	+0.73 +0.73
T2N170W	50m	NINO4	+0.92 +0.92
T2N170W	75m	SOI	-0.74 -0.74
T2N170W	75m	TNI	-0.76 -0.76
T2N170W	75m	ONI	+0.91 +0.91
T2N170W	75m	NINO3.4	+0.81 +0.81
T2N170W	75m	NINO4	+0.93 +0.93
T2N170W	100m	ONI	+0.71
T2N180W	1m	TNI	-0.71 -0.71
T2N180W	1m	NINO4	+0.94 +0.94
T2N180W	25m	NINO4	+0.88 +0.87
T2N180W	50m	TNI	-0.71
T2N180W	50m	NINO4	+0.89 +0.89
T2N180W	75m	TNI	-0.8 -0.81
T2N180W	75m	NINO4	+0.72 +0.72
T2N180W	100m	TNI	-0.75 -0.75

T2N95W	1m	NIINO3	+0.79 +0.77
T2S110W	1m	NINO3	+0.94 +0.95
T2S110W	20m	NINO3	+0.94 +0.94
T2S110W	180m	TNI	-0.76 -0.76
T2S125W	1m	NINO3	+0.94 +0.95
T2S125W	1m	NINO3.4	+0.79 +0.82
T2S125W	20m	NINO3	+0.91 +0.91
T2S125W	20m	NINO3.4	+0.83 +0.82
T2S125W	40m	NINO3	+0.82 +0.81
T2S125W	40m	NINO3.4	+0.87 +0.86
T2S125W	80m	ONI	+0.71 +0.71
T2S140W	1m	ONI	+0.72 +0.74
T2S140W	1m	NINO3	+0.83 +0.81
T2S140W	1m	NINO3.4	+0.93 +0.94
T2S140W	20m	ONI	+0.78 +0.78
T2S140W	20m	NINO3	+0.8 +0.81
T2S140W	20m	NINO3.4	+0.95 +0.95
T2S140W	40m	ONI	+0.78 +0.78
T2S140W	40m	NINO3	+0.76 +0.76
T2S140W	40m	NINO3.4	+0.95 +0.95
T2S140W	60m	ONI	+0.83 +0.83
T2S140W	60m	NINO3.4	+0.87 +0.88
T2S140W	80m	ONI	+0.71 +0.73
T2S155W	1m	ONI	+0.87 +0.86
T2S155W	1m	NINO3.4	+0.95 +0.94
T2S155W	1m	NINO4	+0.9 +0.9
T2S155W	25m	ONI	+0.87 +0.86
T2S155W	25m	NINO3.4	+0.94 +0.94
T2S155W	25m	NINO4	+0.9 +0.9
T2S155W	50m	TNI	-0.71 -0.71
T2S155W	50m	ONI	+0.86 +0.86
T2S155W	50m	NINO3.4	+0.91 +0.91
T2S155W	50m	NINO4	+0.91 +0.91
T2S155W	75m	TNI	-0.71 -0.71
T2S155W	75m	ONI	+0.88 +0.88
T2S155W	75m	NINO3.4	+0.86 +0.86
T2S155W	75m	NINO4	+0.92 +0.91
T2S155W	100m	ONI	+0.71
T2S165E	1m	TNI	-0.81 -0.82
T2S165E	1m	NINO4	+0.84 +0.84
T2S165E	10m	TNI	-0.73 -0.76
T2S165E	25m	TNI	-0.72 -0.74
T2S165E	25m	NINO4	+0.74 +0.73
T2S165E	50m	TNI	-0.78 -0.79
T2S165E	75m	TNI	-0.83 -0.82
T2S165E	100m	TNI	-0.74 -0.73

T2S170W	1m	SOI	-0.75 -0.75
T2S170W	1m	TNI	-0.81 -0.81
T2S170W	1m	ONI	+0.93 +0.94
T2S170W	1m	NINO3.4	+0.85 +0.85
T2S170W	1m	NINO4	+0.95 +0.95
T2S170W	25m	SOI	-0.71 -0.72
T2S170W	25m	TNI	-0.79 -0.79
T2S170W	25m	ONI	+0.93 +0.93
T2S170W	25m	NINO3.4	+0.84 +0.85
T2S170W	25m	NINO4	+0.94 +0.94
T2S170W	50m	SOI	-0.73 -0.73
T2S170W	50m	TNI	-0.8 -0.8
T2S170W	50m	ONI	+0.92 +0.92
T2S170W	50m	NINO3.4	+0.84 +0.84
T2S170W	50m	NINO4	+0.96 +0.96
T2S170W	75m	ONI	+0.87 +0.87
T2S170W	75m	NINO3.4	+0.73 +0.74
T2S170W	75m	NINO4	+0.9 +0.9
T2S170W	100m	SOI	-0.71 -0.71
T2S170W	100m	TNI	-0.79 -0.8
T2S170W	100m	ONI	+0.91 +0.91
T2S170W	100m	NINO3.4	+0.72 +0.75
T2S170W	100m	NINO4	+0.9 +0.92
T2S180W	1m	SOI	-0.77 -0.77
T2S180W	1m	TNI	-0.84 -0.84
T2S180W	1m	NINO4	+0.97 +0.97
T2S180W	25m	SOI	-0.77 -0.77
T2S180W	25m	TNI	-0.82 -0.82
T2S180W	25m	NINO4	+0.97 +0.97
T2S180W	50m	SOI	-0.77 -0.77
T2S180W	50m	TNI	-0.83 -0.83
T2S180W	50m	NINO4	+0.96 +0.96
T2S180W	75m	SOI	-0.76 -0.76
T2S180W	75m	TNI	-0.84 -0.84
T2S180W	75m	NINO4	+0.95 +0.95
T2S180W	100m	SOI	-0.78 -0.78
T2S180W	100m	TNI	-0.84 -0.84
T2S180W	100m	NINO4	+0.93 +0.93
T2S95W	1m	NINO3	+0.83 +0.84
T2S95W	5m	NINO3	+0.82 +0.82
T2S95W	10m	NINO3	+0.86 +0.86
T2S95W	20m	NINO3	+0.89 +0.89
T5N110W	1m	NINO3	+0.9 +0.88
T5N110W	20m	NINO3	+0.84 +0.84
T5N125W	1m	NINO3	+0.83 +0.81
T5N125W	1m	NINO3.4	+0.89 +0.9

T5N125W	10m	NINO3	+0.83 +0.84
T5N125W	10m	NINO3.4	+0.92 +0.92
T5N125W	20m	NINO3	+0.79 +0.8
T5N125W	20m	NINO3.4	+0.88 +0.88
T5N125W	40m	NINO3	+0.74 +0.74
T5N125W	40m	NINO3.4	+0.87 +0.87
T5N140W	1m	ONI	+0.87 +0.87
T5N140W	1m	NINO3.4	+0.9 +0.9
T5N140W	13m	ONI	+0.77 +0.76
T5N140W	13m	NINO3.4	+0.85 +0.86
T5N140W	20m	ONI	+0.83 +0.83
T5N140W	20m	NINO3.4	+0.86 +0.87
T5N140W	40m	TNI	-0.71 -0.71
T5N140W	40m	ONI	+0.87 +0.87
T5N140W	40m	NINO3.4	+0.87 +0.87
T5N140W	60m	TNI	-0.74 -0.74
T5N140W	60m	ONI	+0.82 +0.82
T5N155W	1m	ONI	+0.85 +0.86
T5N155W	1m	NINO3.4	+0.72 +0.73
T5N155W	1m	NINO4	+0.91 +0.91
T5N155W	25m	TNI	-0.73 -0.73
T5N155W	25m	ONI	+0.9 +0.9
T5N155W	25m	NINO3.4	+0.76 +0.76
T5N155W	25m	NINO4	+0.92 +0.92
T5N155W	50m	ONI	+0.88 +0.88
T5N155W	50m	NINO3.4	+0.76 +0.76
T5N155W	50m	NINO4	+0.91 +0.91
T5N155W	75m	ONI	+0.85 +0.86
T5N155W	75m	NINO4	+0.81 +0.82
T5N180W	1m	TNI	-0.74 -0.75
T5N180W	1m	NINO4	+0.84 +0.85
T5N180W	25m	TNI	-0.74 -0.73
T5N180W	25m	NINO4	+0.84 +0.84
T5N180W	50m	TNI	-0.74 -0.75
T5N180W	50m	NINO4	+0.82 +0.82
T5N95W	1m	NINO3	+0.89 +0.87
T5N95W	5m	NINO3	+0.88 +0.88
T5N95W	10m	NINO3	+0.84 +0.84
T5S110W	1m	NINO3	+0.9 +0.91
T5S110W	20m	NINO3	+0.92 +0.92
T5S125W	1m	NINO3	+0.93 +0.93
T5S125W	1m	NINO3.4	+0.72 +0.74
T5S125W	20m	NINO3	+0.92 +0.92
T5S125W	20m	NINO3.4	+0.72 +0.71
T5S125W	40m	NINO3	+0.88 +0.88
T5S125W	40m	NINO3.4	+0.81 +0.81

T5S125W	80m	ONI	+0.72 +0.72
T5S125W	100m	ONI	+0.72 +0.74
T5S125W	120m	ONI	+0.71 +0.73
T5S140W	1m	NINO3	+0.85 +0.84
T5S140W	1m	NINO3.4	+0.88 +0.89
T5S140W	20m	NINO3	+0.89 +0.89
T5S140W	20m	NINO3.4	+0.9 +0.9
T5S140W	40m	NINO3	+0.83 +0.84
T5S140W	40m	NINO3.4	+0.91 +0.91
T5S140W	60m	ONI	+0.73 +0.72
T5S140W	60m	NINO3	+0.74 +0.76
T5S140W	60m	NINO3.4	+0.91 +0.91
T5S140W	80m	TNI	-0.74 -0.74
T5S140W	80m	ONI	+0.79 +0.8
T5S140W	80m	NINO3.4	+0.72
T5S155W	1m	SOI	-0.74 -0.73
T5S155W	1m	ONI	+0.85 +0.85
T5S155W	1m	NINO3.4	+0.95 +0.95
T5S155W	1m	NINO4	+0.84 +0.84
T5S155W	25m	SOI	-0.77 -0.77
T5S155W	25m	ONI	+0.84 +0.83
T5S155W	25m	NINO3.4	+0.94 +0.94
T5S155W	25m	NINO4	+0.84 +0.83
T5S155W	50m	SOI	-0.73 -0.73
T5S155W	50m	TNI	-0.72 -0.71
T5S155W	50m	ONI	+0.85 +0.85
T5S155W	50m	NINO3.4	+0.94 +0.94
T5S155W	50m	NINO4	+0.86 +0.86
T5S155W	75m	TNI	-0.74 -0.73
T5S155W	75m	ONI	+0.86 +0.85
T5S155W	75m	NINO3.4	+0.88 +0.89
T5S155W	75m	NINO4	+0.86 +0.86
T5S155W	100m	TNI	-0.82 -0.81
T5S155W	100m	ONI	+0.78 +0.79
T5S155W	100m	NINO3.4	+0.72
T5S155W	100m	NINO4	+0.79 +0.8
T5S165E	250m	NINO4	-0.73 -0.74
T5S170W	1m	TNI	-0.79 -0.79
T5S170W	1m	ONI	+0.87 +0.86
T5S170W	1m	NINO3.4	+0.84 +0.84
T5S170W	1m	NINO4	+0.87 +0.87
T5S170W	25m	TNI	-0.82 -0.81
T5S170W	25m	ONI	+0.86 +0.86
T5S170W	25m	NINO3.4	+0.8 +0.8
T5S170W	25m	NINO4	+0.86 +0.85
T5S170W	50m	TNI	-0.83 -0.83

T5S170W	50m	ONI	+0.86 +0.86
T5S170W	50m	NINO3.4	+0.85 +0.85
T5S170W	50m	NINO4	+0.89 +0.89
T5S170W	75m	TNI	-0.84 -0.84
T5S170W	75m	ONI	+0.78 +0.78
T5S170W	75m	NINO3.4	+0.75 +0.76
T5S170W	75m	NINO4	+0.86 +0.86
T5S170W	100m	TNI	-0.8 -0.8
T5S170W	100m	NINO4	+0.74 +0.74
T5S180W	1m	SOI	-0.72 -0.72
T5S180W	1m	TNI	-0.79 -0.79
T5S180W	1m	NINO4	+0.91 +0.91
T5S180W	25m	TNI	-0.77 -0.76
T5S180W	25m	NINO4	+0.9 +0.9
T5S180W	50m	SOI	-0.71 -0.71
T5S180W	50m	TNI	-0.79 -0.79
T5S180W	50m	NINO4	+0.9 +0.9
T5S180W	75m	SOI	-0.71
T5S180W	75m	TNI	-0.84 -0.84
T5S180W	75m	NINO4	+0.84 +0.84
T5S180W	100m	TNI	-0.8 -0.79
T5S180W	250m	NINO4	-0.71
T5S95W	1m	NINO3	+0.83 +0.84
T5S95W	20m	NINO3	+0.85 +0.84
T8S125W	80m	TNI	-0.79 -0.79
T8S125W	100m	TNI	-0.72 -0.73
T8S125W	120m	TNI	-0.72 -0.72
T8S155W	75m	TNI	-0.71 -0.72
T8S170W	25m	TNI	-0.72 -0.71
T8S170W	50m	TNI	-0.72 -0.72
T8S170W	75m	TNI	-0.76 -0.76
T9N140W	13m	TNI	-0.73 -0.73 sparse

Table 5. Correlations for salinity at 00 UTC in instances when r >|±0.7|, and their corresponding depth and climate index.

Buoy	depth	S_41-Teleconnection	r value where |r| > 0.7
S0N125W	120m	ONI	+0.71
S0N140W	5m	ONI	+0.73
S0N140W	5m	NINO3	+0.73
S0N140W	5m	NINO3.4	+0.78
S0N140W	10m	ONI	+0.73
S0N140W	10m	NINO3.4	+0.8
S0N140W	20m	ONI	+0.72
S0N140W	20m	NINO3.4	+0.77
S0N140W	40m	NINO3.4	+0.75

S0N140W	60m	NINO3.4	+0.73
S0N165E	5m	SOI	+0.79
S0N165E	5m	TNI	+0.82
S0N165E	5m	NINO4	-0.82
S0N165E	10m	SOI	+0.74
S0N165E	10m	TNI	+0.8
S0N165E	10m	NINO4	-0.87
S0N165E	11m	NINO4	-0.77
S0N165E	25m	SOL	+0.75
S0N165E	25m	NINO4	-0.74
S0N165E	50m	TNI	+0.72
S0N165E	50m	NINO4	-0.75
S0N170W	75m	SOI	-0.8
S0N170W	75m	ONI	+0.71
S0N170W	75m	NINO4	+0.72
S2N165E	1m	NINO4	-0.73
S2N170W	1m	TNI	-0.76
S2N170W	1m	NINO4	+0.72
S2N95W	120m	TNI	-0.78
S2S165E	1m	NINO4	-0.72