Quality-Control of Upper-Air Soundings for PISTON 2018 and MR-18-04 (Version 0)

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1. Introduction

From 21 August 2018 to 12 October 2018, upper-air soundings were collected as part of the PISTON (Propagation of the Intra-Seasonal Tropical Oscillation) field campaign from launches conducted on the *R/V Thomas Thompson* over the Northern Equatorial Western Pacific. Soundings were collected during two cruises of the *R/V Thompson* referred to in this document as legs 2 and 3. The location of the sounding observations during these cruise legs (left panel) and the SST field in the vicinity of the observations (right panel) are shown in Fig. 1.

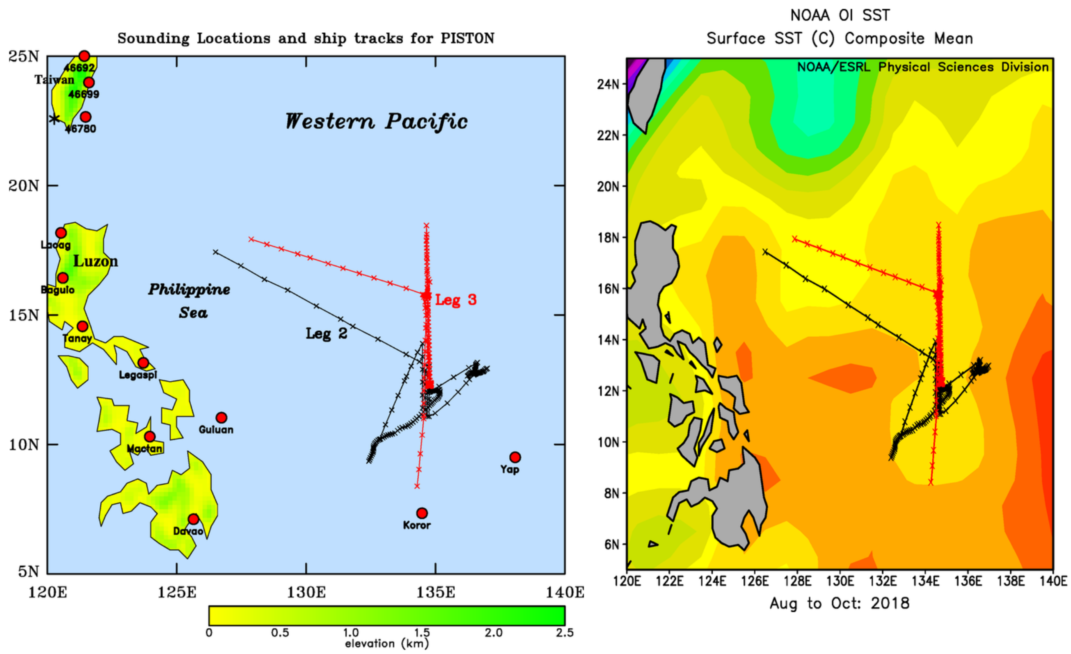

Figure 1. (left) Map showing location of the 375 upper-air soundings taken during the PISTON from the *R/V Thompson* (Leg 2 shown in black, Leg 3 shown in red). Starting location for Leg 2 and ending location for Leg 3 was Kaohsiung Taiwan shown with * symbol. Other upper-air sounding sites in the vicinity are shown with red dots. (right) August-October 2018 mean SST field from NOAA OI analysis. SST scale to right of figure is in (°C).

From 14 August 2018 to 1 September 2018, upper-air soundings were collected as part of the MR-18-04 (Mirai 2018 Cruise 4) field campaign from launches conducted on the *R/V Mirai* over the Northern Equatorial Western Pacific. This cruise was designed primarily to deploy and recover surface moorings. A number of soundings were also launched when the *R/V Mirai* radar was in a dual doppler configuration the *R/V Thompson*. The location of the sounding observations during MR-18-04 are shown in Fig. 2. Red X symbols on this map show the sounding locations when the ships where in the near vicinity to each other.

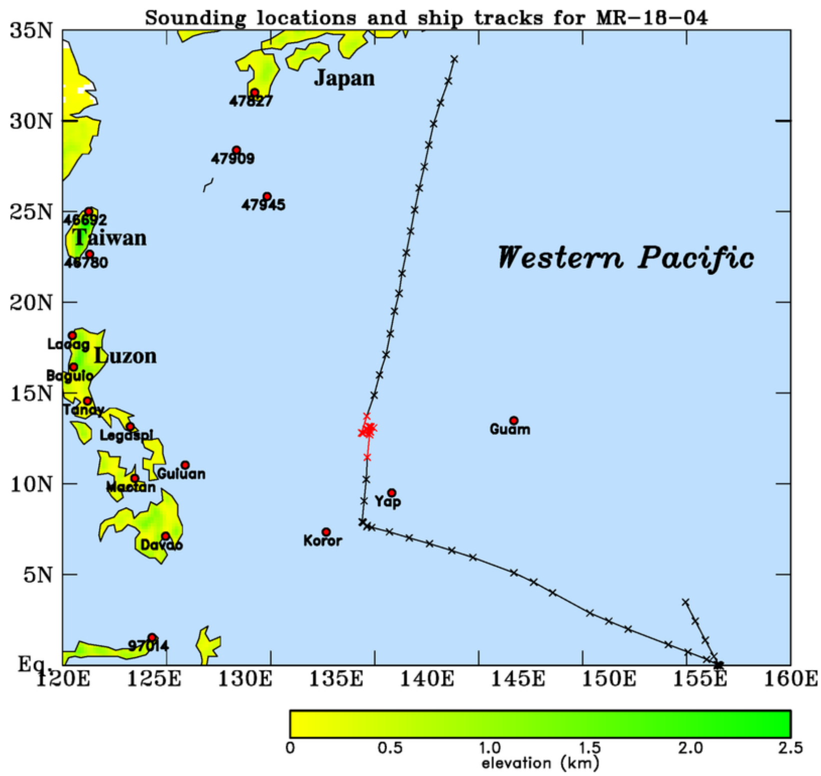

Figure 2. Map showing location of the 90 upper-air soundings taken during the MR-18-04 from the *R/V Mirai.* Red symbols indicate when the two ships were in the near vicinity to each other.

In addition, upper-air soundings were collected and processed from three nearby operational sites (Guam, Yap, and Koror, locations of which are shown in Fig. 2) for the period covering the operation of the ships (14 August – 12 October 2018). This report discusses the Version 0 post-processing of the radiosonde observations taken from these operational sites as well as those collected during the PISTON and MR-18-04 cruises.

2. Overview of PISTON and MR-18_04 sounding operations

A visual inventory of the sounding data taken during PISTON and MR-18-04 is presented in Fig. 2. On the *R/V Thompson* soundings were generally taken 8 times per day (at 00, 03, 06, 09, 12, 15, 18, and 21UTC nominal time; LT = UTC+9). As seen here, 371 out of 375 soundings had data to at least 100 hPa. Sounding on the *R/V Mirai* were generally taken 4 times per day except when the ships were in the near vicinity of each other (24-28 August) when 8/day soundings where made. All of the MR-18-04 soundings had data to at least to 60 hPa. Sound frequency at the operational sites were 2/day at Yap and Guam and 4/day at Koror until 12 September and 2/day thereafter.

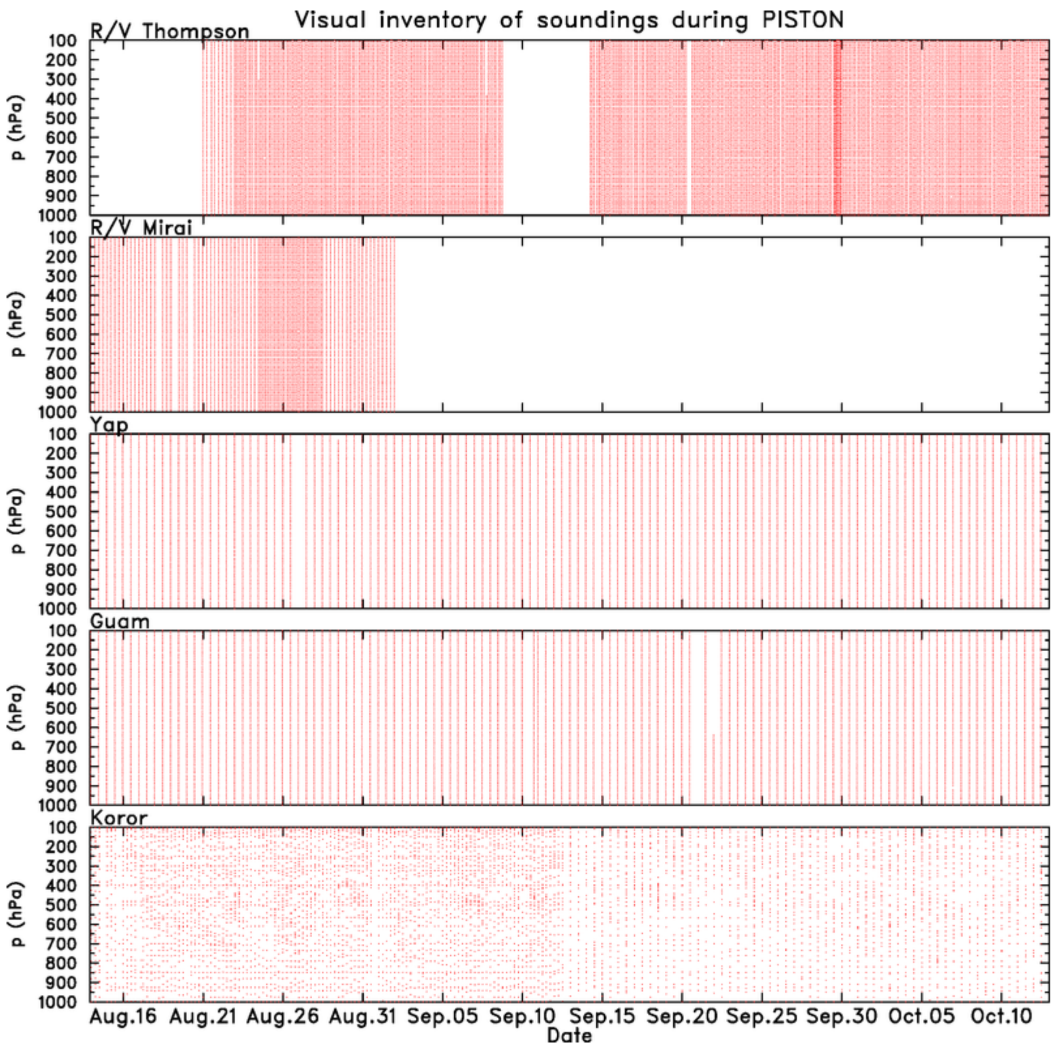

Figure 3. Visual sounding inventory of upper-air data for (from top to bottom) the *R/V Thompson* for 21 August to 12 October 2018, the *R/V Mirai* for 14 August to 1 September 2018 and operational sites (Yap, Guam and Koror) for 14 August to 12 October 2018. Inventory is based on Level 4 data where each line of dots represents a successful sonde launch. The data gap in the top panel from September 9th to 14th was when the *R/V Thompson* had a port call in Palau. Sounding frequency on the *R/V Thompson* increased to 1.5 hr on 29 and 30 September to sample the rain bands of Typhoon Kong-Rey. Sounding frequency on the *R/V Mirai* increased to 3 hr on 24-28 August when ship radars where in dual Doppler configuration.

On the *R/V Thompson*, high-resolution (hi-res) sonde data (1s) were collected and processed with a Digicora MW41 system. The majority RS41 sondes used in PISTON began with serial numbers starting with N51 indicating that they were manufactured between 17 -24 December 2017. The last nine sondes launched began with the serial number P02 which were manufactured between 8-15 January 2018. The sondes were launched using 150 gr balloons. The ground station Digicora software used to process the RS41-SG sondes was version 2.2.1 which includes corrections to the raw humidity data for a daytime solar radiation dry bias and a time-lag error due to slow instrument response at cold temperatures. With these corrections the resulting humidity profiles in tropical soundings have been found to be quite accurate (cumulative measurement uncertainty of 4% RH as reported in Jensen et al. 2016). Wind data were based on GPS wind retrievals which have an stated accuracy of 0.15 m/s (Vaisala 2014). The RS41-SGP sondes have a pressure sensor such that geopotential height is computed using this measured pressure and making use of the hypsometric equation. For *the R/V Thompson* data, GPS altitude is also provided in the Level 1-3 data discussed below. No GPS altitude was saved for the MR-18-04 sondes. For the ships, the station ID numbers (99991 and 99992) were chosen for convenience while the call letters (KTDQ for the *R/V Tommy Thompson* and JNSR for the *R/V Mirai*) were assigned to these ships.

Site	Station ID	Sonde type	Resolution	No. of soundings	Dates of retrieved data
R/V Thompson	99991, KTDQ	RS41-SGP	1 s	375	08/21/2018 - 10/12/2018
R/V Mirai	99992, JNSR	RS41-SGP	1s	90	08/14/2018-09/01/2018
Yap	91413, PTYA	LMS-6	1s	119	08/14/2018-10/12/2018
Guam	91212, PGAC	RS92-NGP	1s	119	08/14/2018-10/12/2018
Koror	91408, PTRO	LMS-6	GTS	177	08/14/2018-10/12/2018

Table 1. Summary information for the *R/V Thompson*, *R/V Mirai* , Yap, Guam and Koror sounding operations during PISTON. Resolution refers to the native time resolution of the data however the Koror data was only available to us at GTS resolution.

3. Quality-control procedures

3a. PISTON soundings from the R/V Thompson

The methodology used to produce a quality-controlled (QC'ed) sounding dataset for PISTON follows that described in Ciesielski et al. 2011. This procedure involves the four stages of processing outlined below.

(1) In this first stage of processing, the surface data in 1-s EDT files created by the DigiCora software were corrected. As it turns out, the software assumed the surface data being entered was from instruments at 19m. However this was not entirely the case. While wind data from an anemometer were at 19 m, the PTU (Pressure, Temperature and Humidity) entered to baseline the soundings were from the SCS (Ship Computer Sensors) at 15.5 m. A second set of PTU measurements at 15.3 m were available from the PSD (Physical Science Division) NOAA sensors. The DigiCora software adjusted the entered surface pressure to the station level (assumed to be 3 m or the height of the ship deck ASL). Since the surface data was actually at or near 15.5 m, the post processing assumed 15.5 m for the bottom sonde level not 3 m.

Some additional errors were made in entering the surface data. The wind data from the mast was displayed in knots but needed to be entered into the DigiCora software in m/s. This conversion was usually, but not always done. Secondly, the surface data entered should be as close as possible to the time the soundings were launched. At times, the surface data entered was representative of a time later than launch time (from a few to several minutes).

A procedure was developed to ensure that the correct surface data were used to baseline the soundings. The surface data used was provided by a NOAA group in Boulder CO with winds being averaged at 1-min and 10-min resolution and PTU data at 1-min resolution. Due to poor ventilation, the SCS temperature sensor experienced overheating during the day (Baruteau Ludovic, personal communication). For this reason, our correction procedure used measurements from the PSD temperature sensor.

Field	Source
Pressure	1-min averaged 15.5 m value from SCS
Temperature	1-min averaged 15.3 m value from PSD sensor
Humidity	1-min averaged 15.5 m value from SCS
Winds	10-minute averaged 19m value from mast anemometer

Table 2. Summarizes where data came from for the procedure to correct the surface data in *the R/V Thompson* soundings.

Notes:

1. The 1-min or 10-min surface value closest to the sonde launch time was used.

2. Due to gustiness in the wind measurements, the 10-min averaged wind was used as it better represents the large-scale conditions in the vicinity of the ship.
3. By using surface data from the well ventilated sensors on the ship mast and not from the deck of the ship, this procedure has the added advantage of mitigating low-level deck heating and cooling effects sometimes found in ship soundings (Yoneyama 2002).

After correcting the surface values, the geopotential height at the first level above the surface (z_1_unc) was recomputed using the hypsometric equation yielding z_1_cor. Since sounding values above the surface did not change, heights above this first level were adjusted by the difference between the corrected and old heights (i.,e., z_1_cor – z_1_unc).

For whatever reason, the surface values for the sonde launch on 11 October 12UTC (nominal time) were not entered in real time (see sounding log notes) such that an EDT file was not generated. Thus the DigiCora software was used to stimulate this sounding and produce its EDT file. Once created, it was necessary to correct the file name and the date/time stamp within the file to reflect the correct time.

These "EDT" files were then converted into an ASCII format file (i.e., the CSV format commonly used by NCAR EOL).

Number of sondes used	384
Number of good launches	375
Mean ascent rate*	3.98 m/s
Mean duration of sounding	1 hour 42 minutes
Mean altitude reached	23.78 km
Mean pressure reached	34.74 hPa

Table 3: Some key statistics from the Level 0 *R/V Thompson* dataset. * Note: the optimal ascent rate for a Vasiala RS41 sonde is 4 m/s.

(2) Next, the high-vertical resolution (1-s) sounding data were passed through a series of automated QC algorithms to systematically detect bad values. For this purpose we used ASPEN (Atmospheric Sounding Processing ENvironment), a software tool developed by NCAR EOL. In addition to removing egregious data based on several objective QC checks (e.g., gross limit, vertical consistency, etc), ASPEN filters the winds, computes geopotential height, smooths pressure and writes out the processed QC'ed sounding data in a standard ASCII format used by NCAR EOL.

Level 2 processing note: Two soundings (24 August 1142 UTC and 07 September 1726 UTC) experienced very slow and sometimes negative ascent rates beginning around the freezing level (~580 hPa) due to heavy icing on the balloon. ASPEN considered height data above this level as bad and thus set the height field to missing above this level. If the user wishes to access the height data above 582 hPa for the 24 August sonde, they will need to refer to the level 0 or level 1 data.

(3) In Level 3 (L3) processing, sonde biases and errors are identified and reduced if possible. Unfortunately no collocated independent measurements of precipitable water (PW) were available to further check the reliability of the RS41 moisture data, so no corrections of this type were applied. A number of the daytime sounding exhibited some deck heating effects. These soundings were visually identified using the xsnd software (a visual sonde editor) and suspect points were marked as questionable in the uniform 5-hPa files. These soundings were then corrected (both hi-res and 5-hPa) using a scheme suggested by Yoneyama et al. (2002). In this scheme gradients of T and T_d are computed using good points directly above suspect points. These gradients are then used to extrapolate new values of T and T_d down to the surface. In total, 82 *R/V Thompson* soundings were identified as having deck effects. Adjustment of these sounding resulted in a mean surface T decrease of 0.37°C and a mean T_d increase of 0.34°C for these 82 soundings. Note QC flags for corrected T and T_d values were set to "good".

In addition to the deck effect correction, an unrealistic change in the GPS horizontal position between the surface and first data point above the surface was frequently noted. For example, the position change was often on the order of 5 km and as large as 26 km. Since the time difference between the surface and first point was generally only a few seconds, these large jumps are clearly unrealistic. It was determined (Holger Vomel, personal communication) that this jump is most likely due to an error in the Vaisala software which assigns the surface position to the GPS location at the time the sounding is initialized in its set-up procedure. Thus with a moving ship as the delay between the sonde initialization time and launch time increases, this position jump becomes more significant. To mitigate this issue, the sonde position at the three data points above the surface was used to extrapolate a new surface position.

(4) Finally, in Level 4 (L4) processing a more "user-friendly" version of the sounding dataset was created with QC flags assigned to each variable providing a measure of the data's reliability. In L4 processing the L3 hi-res data are vertically interpolated to create values at uniform 5-hPa pressure intervals. Suspicious data were identified through application of both objective QC test as in Loehrer et al. (1996) and subjective adjustment of QC flags by visual inspection (Ciesielski et al. 2011) using an in-house developed visual sonde editor (i.e., xsnd). The visual inspection was necessary to ensure a research-quality dataset since subtle errors in sonde data are often difficult to identify with objective procedures. By flagging

suspect data values, the reliable data are easily retrievable with the user deciding what level of quality is acceptable for their analyses. The definition of the QC flags used in the L4 dataset is provided in Table 3.

This second pass of QC checks and visual inspection, beyond those in L2, ensures the veracity of the data and provides yet another filter for identifying suspicious values. Note that the QC checks and visual inspection in L4 processing do not change any data values, only data quality flags. Additional details on interpolating the data to uniform pressure intervals, objective tests for assigning QC flags, and the visual editor used to expedite this processing, can be found at: www.eol.ucar.edu/projects/sondeqc/.

Flag Value	Meaning
1	parameter good
2	parameter "objectively" questionable
3	parameter "visually" questionable
4	parameter "objectively" bad
5	parameter "visually" bad
6	parameter interpolated
7	parameter estimated
8	parameter unchecked
9	parameter missing

Table 4. Convention used for the Level 4 (L4) QC flags.

3b) MR-18-04 soundings from the R/V Mirai

The sounding QC for the *R/V Mirai* follows a similar procedure to that for the *R/V Thompson* except as noted below.

Level 0 – no changes were made to the surface data in the soundings

Level 3 – The Yoneyama et al. (2002) correction was applied to all soundings and was performed by Masaki Katsumata of JAMSTEC. The GPS latitude/longitude position of the surface point was also corrected as discussed in the previous section.

3c) Soundings for operational sites: Yap and Guam

The sounding QC for these sites with high vertical resolution data follows a similar procedure to those of the ships except as noted below.

Level 0 – NWS operational format converted to CSV ASCII format files. No surface corrections were performed.

Level 3 – The same as Level 2; no corrections were applied.

3d) Soundings for operational site: Koror

The high vertical resolution data for this site was provided in a BUFR format that our programs and those at NCAR EOL were unable to read. Thus the GTS resolution data was grabbed from the U of Wyoming sounding archive at http://weather.uwyo.edu/upperair/sounding.html. This data was converted to a level 4 product which was visually inspected to set QC flags on suspicious data. There are no Level 1-3 data for this site.

4. **Data Archive and value added products**

A summary of the various sounding datasets is provided in Table 5 below.

Level 0 (L0.0)	Raw, original native resolution data (DigiCora EDT format), corrected to use QC'ed surface data and height recomputed
Level 1 (L1.0)	Data in common ASCII (i.e., CSV) format, native resolution
Level 2 (L2.0)	Data processed with ASPEN. Native resolution (ASCII EOL format)
Level 3 (L3.0)	Native resolution (ASCII EOL and netcdf formats)
Level 4 (L4.0)	Soundings visually inspected with QC flags; if available hi-res data interpolated to uniform 5-hPa intervals (ASCII and netcdf formats); skew-T diagrams for all soundings

Table 5. Dataset summary and naming convection

Datasets are referenced by both a level number and version number. This report discusses processing of the version 0 data. If further updates are needed, the version number will be incremented accordingly.

In addition to the user-friendly L4.0 dataset, a suite of value added products were generated. These products include skew-T log-P thermodynamic diagrams for each sounding along with computation of various convective parameters (based on L4.0 data). The skew-T diagrams, an example of which is shown in Fig. 4, are provided as png images contained in a single compressed tar file. Table 6 lists the cruise means of the convective parameters for each site. Here CAPE and CIN were calculated assuming irreversible pseudoadiabatic ascent (i.e, condensed water assumed to be removed) using mean thermodynamic conditions in the lowest 50 hPa.

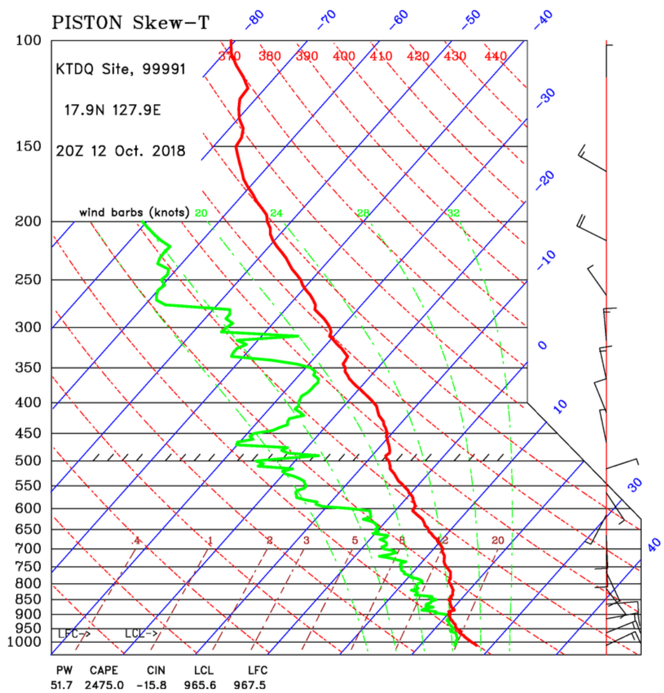

Figure 4. Skew T log-P thermodynamic diagram for 12 October 2018 at 20 UTC sounding taken from the *R/V Thompson*. Convective parameters are listed along bottom of diagram computed using L4.0 data.

Site/ID	PW (mm)	CAPE ($J\ kg^{-1}$)	CIN ($J\ kg^{-1}$)	LCL (hPa)	LFC (hPa)	EL (hPa)
R/V/ Thompson 99991	56.1 (374)	2038.6 (374)	-30.8 (374)	952.6 (374)	922.0 (374)	129.4 (374)
R/V Mirai 99992	55.5 (90)	1974.7 (90)	-34.6 (90)	949.4 (90)	921.3 (90)	130.5 (90)
Yap 91413	55.9 (119)	1602.7 (119)	-44.3 (119)	945.4 (119)	888.9 (119)	128.0 (119)
Guam 91212	56.0 (119)	1658.6 (119)	-48,3 (119)	942.7 (119)	874.6 (119)	133.6 (119)
Koror 91408	52.7 (162)	1482.6 (162)	-46.7 (162)	943.1 (162)	884.1 (162)	135.7 (162)

Table 6: Cruise-mean convective parameters using L4.0 data: PW signifies total-column precipitable water, CAPE – convective available potential energy, CIN – convective inhibition, LCL – lifting condensation level, LFC – layer of free convection, EL – equilibrium level. Numbers in parentheses indicate the number of soundings that went into each average.

Time series of various convective parameters along with SST and the latitude location of the observations for the *R/V Thompson* are shown in Fig. 5.

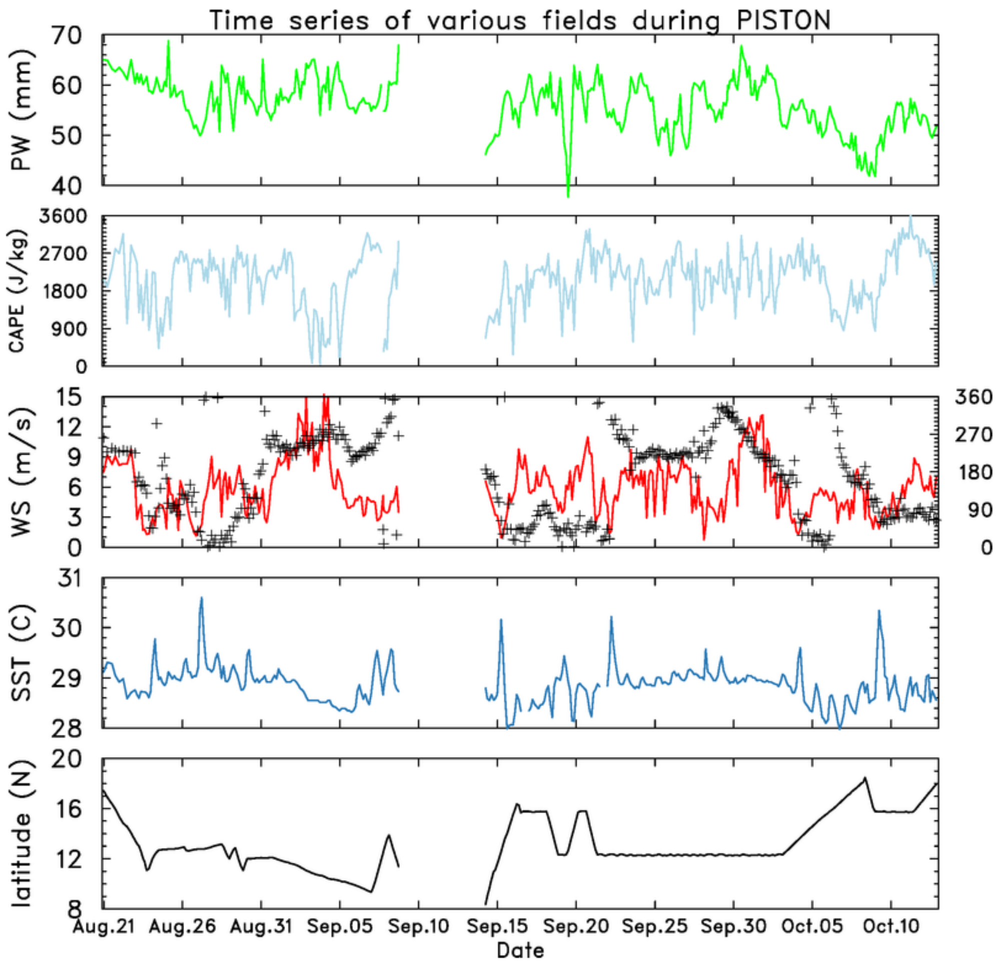

Figure 5. Time series for various field from the *R/V Thompson* during the PISTON cruise. From top to bottom: PW (mm), CAPE (J/kg), wind speed (m/s, scale to left) and wind direction (scale to right), SST (C) and latitude of observations.

5. Summary

During the 21 August 2018 to 12 October 2018 period, 375 upper-air soundings were collected as part of the PISTON field campaign from the *R/V Thompson.* In conjunction with PISTON, soundings were also collected from the *R/V Mirai*, and three operational island sites in the vicinity of these ships (Guam, Koror and Yap). Sounding data from these sites were processed and quality-controlled to produce a high-quality dataset suitable for research applications.

Sounding datasets for all sites can be found at:
http://johnson.atmos.colostate.edu/public/paulc/PISTON/upa_soundings

Data for all of levels of processing (0-4) are provided in ASCII format, while Level 3 and 4 datasets are also provided in netcdf format. A sample fortran programs can be found at above link to read the L1-L4 ASCII datasets.

Questions regarding this dataset and its processing should be directed to Paul Ciesielski (paulc@atmos.colostate.edu).

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6. References

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