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1 **Constraining the Solomon Sea as a Source of Al and Mn to the Equatorial**  
2 **Undercurrent**

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18 **Highlights**

19 Al and Mn are not significantly enriched during transit through the Solomon Sea.

20 Fluxes of Al and Mn into and out of the Solomon Sea are almost equal.

21 Al and Mn are elevated near continental shelves and margins in the Solomon Sea.

22 Local enrichments must be balanced by boundary exchange and scavenging processes.

23 Water exiting the Solomon Sea accounts for ca. half the flux of Al and Mn in the EUC.

24 **Abstract**

25 Total dissolvable and dissolved aluminum (TDAI, DAI) and manganese (TDMn, DMn)  
26 concentrations were measured at 12 stations in and around the Solomon Sea in 2012 as part of  
27 the GEOTRACES GP-12 cruise. These data were used to determine the potential for the  
28 Solomon Sea to act as a source of Al and Mn to the Equatorial Undercurrent (EUC). From a net  
29 budget perspective, waters entering the Solomon Sea at the time of the cruise were already  
30 enriched in Al and Mn, and as that water transited through the Solomon Sea, further net  
31 enrichments were small compared to overall concentrations of these metals. Despite this overall  
32 balance, on a local scale, we observed enrichment of Al and Mn at stations located near  
33 coastlines, most likely caused by sediment scouring by strong currents. Calculated fluxes of DAI,  
34 and TDAI out of the Solomon Sea relative to the EUC are large enough to account for about  
35 three quarters of their respective budgets within the EUC, while the DMn and TDMn fluxes  
36 exiting the Solomon Sea can only account for about half of their respective budgets in the EUC.  
37 These fluxes are subject to high temporal variability and to uncertainty of the relative  
38 contributions of Northern and Southern Hemisphere water mass to the EUC.

39 **Keywords:**

40 Aluminum, Manganese, Solomon Sea, Equatorial Undercurrent, GEOTRACES

41

42

43 **1. Introduction**

44 The Equatorial Undercurrent (EUC) flows at ~200 m depth along the equator at a rate of 20-30  
45 Sv, transporting water, nutrients, and trace elements (e.g., aluminum (Al), and manganese (Mn),  
46 and iron (Fe)) from the Western Pacific to the Eastern Pacific in less than a year (Tsuchiya et al.,  
47 1989). There, it shoals in the photic zone of the High Nutrient, Low Chlorophyll (HNLC) region  
48 of the eastern equatorial Pacific—where ~20% of the world's new primary productivity takes  
49 place (Coale et al., 1996). Understanding sources of trace elements to the EUC is thus important  
50 to better understanding the factors that contribute to primary productivity in the eastern  
51 equatorial Pacific and its contribution to the global carbon cycle.

52 Concentrations of Al, Mn, (and Fe) are elevated in the EUC, relative to open ocean values  
53 (Coale et al., 1996; Gordon et al., 1997; Kaupp et al., 2011; Slemmons et al., 2010, 2012) with  
54 concentrations increasing westward. In the western equatorial Pacific, the major water sources to  
55 the EUC are two low-latitude western boundary currents, the New Guinea Coastal Undercurrent  
56 (NGCU) coming from the south and the Mindanao Current from the north, with the NGCU being  
57 the more important of the two (e.g., Tsuchiya et al., 1989; Grenier et al., 2011, 2013). The  
58 NGCU originates in the Solomon Sea (Fig. 1) where it comes in contact with the coastlines of  
59 volcanic islands with abundant natural and anthropogenic runoff. As a result, the Solomon Sea is  
60 considered to be an important source of trace metals, especially Al and Fe, to the NGCU and  
61 thus the EUC. This conclusion is supported by both modeling studies and geochemical  
62 measurements within the current (Lacan and Jeandel, 2001, 2005; Mackey et al., 2002a,b;  
63 Slemmons et al., 2009; Kaupp et al., 2011; Qin et al., 2015; Pham et al., 2019). Here we report on  
64 dissolved and total dissolvable Al (DAI; TDAI) and Mn (DMn; TDMn) collected from seven  
65 stations within the Solomon Sea and five stations just outside of it during the 2012 PANDORA  
66 cruise (GEOTRACES GP-12). While several trace metal profiles have been collected within the  
67 Solomon Sea and in the neighboring Bismarck and Coral Seas (Mackey et al., 2002a,b; Obata et  
68 al., 2008), those studies were not part of a broader interdisciplinary study. The PANDORA

69 cruise discussed here included a major physical oceanographic component that examined the  
70 major currents flowing through the Solomon Sea (Ganachaud et al., 2017). The combination of  
71 these chemical and physical oceanographic data enables examination of the trace metal budget of  
72 the Solomon Sea, and in turn, its importance to the trace metal budget of the EUC. The data  
73 presented here suggest that the waters entering the Solomon Sea were enriched in trace metals  
74 prior to entering the basin and that their transit through the basin resulted in only a minor net  
75 increase of Mn and Al to these waters.

### 76 *1.1 Geographic Setting: The Solomon Sea*

77 The Solomon Sea is a semi-enclosed basin bounded by the islands of Papua New Guinea (PNG)  
78 to the west, New Ireland and New Britain to the north, and the Solomon Islands to the east, and  
79 is open to the southeast (Fig. 1). An important oceanographic characteristic of this region is the  
80 flow of the New Guinea Coastal Current/ Undercurrent system (NGCC/NGCU) through the  
81 basin. This large current system transports water into the Solomon Sea at depths of 0 - 1400 m  
82 with the strongest transport (40-80 cm/s) being within the thermocline waters that feed the EUC,  
83 at ~ 200 m (Lindstrom et al., 1987; Tsuchiya et al., 1989; Cravatte et al., 2011; Germaineaud et  
84 al., 2016; Alberty et al., 2019). The large transport and associated current speeds result in  
85 relatively short residence time for waters in the Solomon Sea (e.g., ~ 4 months for thermocline  
86 waters). The waters that make up the NGCU originate as the Southern Equatorial Current (SEC),  
87 which flows west between ~5°N and 20°S. As the SEC encounters islands in the Coral Sea, it  
88 branches into various currents, including the North Vanuatu Jet (NVJ) and the New Caledonia  
89 Jet (NCJ, Kessler and Cravatte, 2013; Germaineaud et al., 2016). The NCJ further bifurcates  
90 around 18°S into the North Queensland Current (NQC), which flows north through the northern  
91 Coral Sea and the Gulf of Papua, and around the southern coast of PNG before joining the NVJ  
92 to form the NGCU (Fig. 1; Sokolov and Rintoul, 2000). In the surface ocean (0 – ~150 m), in  
93 addition to the NGCU and NVJ, waters from the SEC flow into the Solomon Sea through gaps  
94 between the Solomon Islands (Hristova and Kessler, 2012) and through the Solomon Strait

95 (Germineaud et al., 2016; Albery et al., 2019). Most of the surface water exits through the  
96 Vitiaz Strait, with some flowing through the St. George's Channel and/or the Solomon Strait  
97 (e.g., Albery et al., 2019). The direction of flow through the Solomon Strait varies seasonally,  
98 and on a net annual basis flows into the Solomon Sea (Albery et al., 2019). The thermocline  
99 waters of the NGCU flow at a depth of ~200 m along the eastern PNG coast and bifurcate south  
100 of New Britain where northwestward flow exits through the Vitiaz Strait (Tsuchiya et al., 1989);  
101 the remainder flows eastward as the New Britain Coastal Undercurrent (NBCU) (Melet et al.,  
102 2010). The NBCU bifurcates around New Ireland, with the western limb flowing out of Saint  
103 George's Channel as the Saint George's Undercurrent (SGU), while the eastern limb exits out  
104 the Solomon Strait as the New Ireland Coastal Undercurrent (NICU; Butt and Lindstrom, 1994).  
105 The NICU then combines with the EUC (Fig. 1; Germineaud et al., 2016). The deeper sub-  
106 thermocline (450-1400m,  $26.9\sim 27.5\sigma_\theta$ ) circulation in the Solomon Sea is also dominated by the  
107 NGCU, however at much reduced levels of transport. Here, as the NGCU approaches the  
108 Woodlark Archipelago it is pushed eastward over this depth range; below 1000 m it passes  
109 through, over and around the submarine extension of the Woodlark Archipelago. This deep water  
110 exits through the Vitiaz Strait (~65%) and Solomon Strait (~30%; Albery et al., 2019), but with  
111 some seasonal variability.

112 The western equatorial Pacific is temporally variable on both seasonal (monsoonal) and  
113 interannual ( ENSO) scales. This variability leads to fluctuations in transport through the  
114 Solomon Sea and the EUC, and is accompanied by changes in river input and surface circulation  
115 (Cresswell, 2000; Melet et al., 2013; Delcroix et al., 2014). Seasonal differences in transport and  
116 circulation in the Solomon Sea have been studied during the PANDORA (austral winter 2012)  
117 and MOORSPICE (austral summer 2014) cruises. Both cruises occurred during a neutral El Niño  
118 phase, and demonstrated that the overall flow into and out of the Solomon Sea was enhanced  
119 during austral winter (PANDORA) (Germineaud et al., 2016). While overall transport through  
120 the Solomon Sea varies seasonally, modeling studies have shown that transport through the  
121 Vitiaz Strait exhibits less temporal variability, presumably because transport through the strait is

122 mainly controlled by bathymetry (narrow, 1200 m deep channel) which restricts water flow,  
123 while seasonality changes are a result of changes in flow of the NVJ and NQC upstream (Melet  
124 et al., 2010). These changes are observed further downstream, in strong temporal variability in  
125 the current flow through Saint George's Channel and the Solomon Strait. Historical observations,  
126 however, do show variation in the transport through the Vitiaz Strait, with intensification during  
127 positive El Nino phase (Lindstrom et al., 1987; Butt and Lindstrom, 1994; Murray et al., 1995).  
128 Modeling studies have also observed intensification of the NGCU during El Nino events, which  
129 creates eddies, causing increased contact with the PNG shelf (Ryan et al., 2006). While models  
130 predict intensification of the NGCU, during the El Nino event of 1991/1992, Murray et al. (1995)  
131 observed a weakening of the EUC, where the maximum velocity during neutral El Nino was  
132 observed at 90 cm/s, and then dropped to 20 cm/s during peak El Nino. The EUC also varies  
133 seasonally, and is stronger in austral winter and weaker in austral summer (Melet et al., 2010).

134

135 The waters that flow through the Solomon Sea are subject to many potential chemical inputs  
136 from the margins, rivers, runoff, mine tailings, and volcanic and hydrothermal activities; it is  
137 thus thought that the NGCU should undergo significant chemical enrichments as it passes  
138 through the Solomon Sea (Lacan and Jeandel, 2001, 2005). Islands in this region are young and  
139 easily eroded, leading to large lithogenic inputs via rivers (e.g., Milliman et al., 1999; Sholkovitz  
140 et al., 1999). Two very large rivers empty into the ocean along the pathway of the major currents  
141 flowing through the region: the Sepik River empties into the Bismarck Sea, thus contributing to  
142 the NGCU as it exits the Solomon Sea, and the Fly River empties into the northern Coral Sea  
143 where it alters the chemistry of the North Queensland Current (Fig. 1). The Sepik River and Fly  
144 River estuaries are two very different systems: The Sepik river system is located over a steep and  
145 narrow shelf, such that river sediments are discharged directly into the ocean (Milliman et al.,  
146 1999, Sholkovitz et al., 1999; Kineke et al., 2000). Sedimentation occurs on the shelf through the  
147 settling of sinking particles from the surface plume, as well as via hyperpycnal flows, which



148 transport sediment to intermediate depths along isopycnals (Kineke et al., 2000). The Fly River  
149 is a shallow estuary where sediment deposition and resuspension impacts the chemical makeup  
150 of the surface water. The Fly River has a high sediment load ( $85 \times 10^9$  kg/year) relative to its  
151 discharge ( $220 \text{ km}^3$  /year) (Salomons and Eagle, 1990). These sediments are dominated by  
152 resuspension due to intense tidal activity, and bioturbated muds in this region have been shown  
153 to have elevated Al, Mn, and Fe fluxes (Harris et al., 1993; Alongi et al., 1996).

154 The Fly river, in addition to having a large sediment load due to its strong relief, high rainfall,  
155 and easily erodible rock, (e.g., Harris et al., 1993) is impacted at its head waters by increased  
156 contamination from the Ok Tedi mine. This ore deposit, and others in the area, are a result of  
157 elevated tectonic and volcanic activity in the region. Over the life of the Ok Tedi mine it is  
158 estimated that it was responsible for the input of 66 million tons per year of mine tailings,  
159 including 24 million tons per year of mill fines (e.g., Hettler et al., 1997). Tailings from mines  
160 throughout the region are delivered to the ocean through run off, smaller rivers, and erosion, and  
161 a portion of this waste reaches the coastal ocean, where it might be entrained into the NQC.

162 A seafloor spreading-center in the Woodlark Basin in the eastern Solomon Sea hosts  
163 hydrothermal vent systems at  $>2500\text{m}$  (e.g., Laurila et al., 2012) and undersea-volcanos in the  
164 region are hydrothermally (McConachy et al., 2002; Laurila et al., 2012) and volcanically active  
165 (McConachy et al., 2002); the eruption of Kavachi volcano in the surface ocean is notable (Baker  
166 et al., 2002; Phillips et al., 2016). In the shallow ocean both diffuse and focused venting have  
167 been observed at Tutum Bay on the northeastern side of the Solomon Sea, enriching the surface  
168 waters in Fe and Mn, though these concentrations only persist near the vent sites (Pichler et al.,  
169 1999). In coastal regions, runoff from Rabaul volcano ( $4^{\circ}14'25''\text{S}$ ,  $152^{\circ}11'45''\text{E}$ , east of New  
170 Britain) was measured to be high in Fe (Labatut et al., 2014), and ash from Rabaul's eruptions  
171 are deposited onto the ocean surface with precipitation being slightly acidic from the volcanic  
172  $\text{SO}_2$  (Ganachaud et al., 2017). The elevated tectonic and magmatic activity in this region  
173 suggests that other, undiscovered hydrothermal vent sites likely exist, and this region has been

174 extensively explored for deep-sea mining of hydrothermally-sourced minerals (e.g., Jankowski,  
175 2011).

## 176 ***1.2 Sampling locations***

177 The PANDORA cruise (GEOTRACES GP-12) took place during austral winter 2012 (28 June–6  
178 August) aboard the R/V *l'Atalante* and was led by the Laboratoire d'Etudes en Geophysique et  
179 Oceanographie Spatiales (LEGOS, Chief Scientist G. Eldin). A more detailed description of  
180 hydrographic data and geochemical sampling, as well as preliminary findings about this cruise,  
181 can be found in Ganachaud et al. (2017). A total of 170 casts were collected at 83 stations in and  
182 around the Solomon Sea. The 12 stations that are examined in this study (Fig. 1a) were sampled  
183 using a trace-metal clean rosette according to GEOTRACES protocols. Five of these stations  
184 were located outside of the Solomon Sea: three to the south of the entrance (stations 4, 10, and  
185 82), one to the northeast near the Solomon Strait (station 43), and one northeast of the Solomon  
186 Archipelago (station 13). Within the Solomon Sea, one station was located on the west side of  
187 the Solomon Islands, off San Cristobal (station 21). Two stations were located within the flow  
188 path of the NGCU near Trobriand Island (stations 39 and 71). In the northern Solomon Sea,  
189 stations are located in the Vitiaz Strait (station 77), near the Solomon Strait (station 42), and  
190 along the flow path of thermocline waters as they exit via Saint George's Channel (station 60).  
191 One station is located at the southern entrance of the Solomon Sea, off the coast of Rossel Island,  
192 PNG (station 34) and was only sampled to 350m.

## 193 **2. Methods**

194 Water sampled for Al and Mn was collected using an epoxy-coated titanium CTD Rosette with  
195 twelve 12-L Go-Flo bottles and described in more detail in Ganachaud et al. (2017) . Go-Flo  
196 bottles spent minimal time on-deck, and after filling were transported to a clean-air environment  
197 for sub-sample removal and storage between casts. Total acid-soluble metal samples, which  
9

198 includes the dissolved fraction plus the acid soluble portion of particles present in unfiltered  
199 samples (abbreviated as TD – total dissolvable, based on the terminology of Mackey et al. 2002a  
200 and Slemons et al. 2010) were collected directly from Go-Flo bottles into acid-cleaned 100 mL  
201 LDPE bottles (with LDPE caps). Dissolved metal (D) samples were collected from the Go-Flo  
202 bottles using slight overpressure of filtered N<sub>2</sub> for filtration through 0.2 µm Sartobran-300  
203 capsule filters into acid-cleaned 100 mL LDPE bottles (with LDPE caps). All samples were  
204 acidified to 0.024 N using Optima HCl one month prior to Al analysis, and six months prior to  
205 Mn analysis.

206 Al was analyzed by flow injection analysis (FIA) using direct injection and fluorescent detection  
207 of the Al-lumogallion complex, following Resing and Measures (1994). This method had an  
208 average detection limit of 0.85 nM, which is 34% of the lowest concentration measured, and 7%  
209 of the average concentration of all samples. GEOTRACES GD (consensus ± 1 SD = 17.7 ± 0.2  
210 nM) reference standard was run daily, with an average value of 19.49 ± 0.88 nM (1 SD, n = 17).  
211 We acknowledge that this value is higher than the reported consensus value, but we are not able  
212 to identify any blanks in our system based on the methodology that was used here. We note that  
213 the reference material is fairly old (GEOTRACES GD was collected 11 years prior to these  
214 analyses), and has been stored with HDPE caps, which are known to cause contamination for Al  
215 (Brown and Bruland, 2008). Other analysts have found consistently elevated Al values for the  
216 low nM level GEOTRACES standards (e.g. Resing et al., 2015; Singh et al., 2020). Daily  
217 precision for standards was on average 3.4% relative standard deviation (RSD) at 1 nM and 2.2%  
218 RSD at 20 nM.

219 Mn was analyzed by FIA using in-line preconcentration of Mn onto an 8-hydroxyquinoline  
220 column and spectroscopic detection of leucomalachite green, based on the method of Resing  
221 and Mottl (1992), with the addition of 4 g of nitrilo tri-acetic acid per liter to the ammonium  
222 acetate reaction buffer. This method had a detection limit of 0.027 nM, which is 14% of the  
223 lowest sample measured and 3% of the average concentration of all samples measured.

224 GEOTRACES GD (consensus  $\pm$  1 SD =  $1.50 \pm 0.11$  nM) standards were run at least once a day  
225 and measured to be  $1.80 \pm 0.19$  (1 SD, n = 17). Daily precision for standards was on average  
226 3.0% RSD at 0.1 nM and 2.0% RSD at 1.0 nM. An internal consistency standard was run at least  
227 twice daily and found to be  $0.32 \text{ nM} \pm 0.02 \text{ nM}$  (1 SD, n = 94).

## 228 *2.1 Calculation of a trace metal budget in the Solomon Sea*

229 To examine the net impact on water passing through the Solomon Sea, we construct a budget to  
230 evaluate the fluxes into and out of the Solomon Sea at three density intervals, based on transport  
231 estimates calculated for the PANDORA cruise by Germaineaud et al. (2016): Surface layer (surf –  
232  $24\sigma_\theta$ ), Thermocline layer or NGCU ( $24\text{--}26.9\sigma_\theta$ ), and Deep layer ( $>26.9\sigma_\theta$ ; our maximum  
233 sampled  $\sigma_\theta$  is  $27.54/1300$  m). For the thermocline layer ( $24\sigma_\theta\text{--}26.9\sigma_\theta$ ), we can also compare  
234 these fluxes to the flux of the trace metals at the Equatorial Undercurrent to evaluate the  
235 contribution of the Solomon Sea trace metal pool to that of the EUC (section 4.2).

236 The depth-weighted average concentration over each density interval is calculated using a  
237 trapezoidal integration over the depth range corresponding to potential density for each station  
238 and is reported in Table 1. The corresponding depths for each density interval can be found in  
239 Table S1 and the full dataset can be found in Table S2. Errors reported in the text and in the  
240 tables represent one standard deviation calculated using the analytical error on each  
241 measurement.

242 This budget considers that there is a background flux of Al and Mn entering the Solomon Sea  
243 over each of the three potential density ranges, referred to here as the Solomon Sea Inflow. The  
244 outflow budget considers outputs through the Vitiaz Strait (station 77), St. George's Channel  
245 (station 60) and the Solomon Strait (station 42), which we refer to collectively as the Solomon  
246 Sea Outflow. Germaineaud et al. (2016) reported outflow values for the Vitiaz Strait and the sum

247 of the outflow for the water leaving via the Solomon Strait and St. George's Channel. Because  
248 they do not report individual outflows for these two straits, we assume their outflows to be equal.  
249 While Alberty et al. (2019) estimate transport through each channel, it is on an annual basis and  
250 not over shorter time intervals. This is important because the flows are seasonally variable with  
251 water flowing both into and out of the Solomon Strait based on season. During PANDORA,  
252 surface water was flowing out of the Solomon Sea via Solomon Strait, rather than into it, as it  
253 does on a net annual basis (Alberty et al., 2019). For these reasons, we find that the estimates  
254 provided by Germaineaud et al. (2016) are the best to use for this budget.

255 Chemical influx and efflux are calculated by considering transport and the concentrations of each  
256 DAl, DMn, TDAI, and TDMn at appropriate stations as follows:

257 
$$\text{Flux (moles/s)} = \text{volume transport (m}^3/\text{s)} \times [\text{element}] \text{ (moles/m}^3\text{)}$$

258 For the efflux, transport out of the Solomon Sea is considered for each of the exit straits  
259 combined with the depth-weighted average concentration at stations closest to them.

260 The specific assumptions and processes used to determine average concentration for each flux  
261 are described below.

### 262 2.1.1 Inflow

263 We assume the Al and Mn concentrations at stations 10 and 82 to be representative of those  
264 flowing into the Solomon Sea. Station 10 is located where water flows across the Vanuatu  
265 Archipelago via the North Vanuatu Jet, while station 82 is located in the middle of the Coral Sea,  
266 farther away from potential shelf inputs, and likely is dominated by water flowing via the NQC.  
267 Station 34, which is the station likely to be most representative of the NGCU inflow, was not

268 sampled through the potential density range of the EUC due to bad weather, and also shows  
269 elevated Al relative to other profiles within the Solomon Sea, suggesting shelf input, and we  
270 have therefore chosen not to consider it as a background profile. While a full profile of trace  
271 metal samples was not collected for station 34, a standard CTD-rosette package collected a full  
272 depth CTD profile, which shows that temperature, salinity, oxygen, and potential density profiles  
273 at this station appear to be intermediate between stations 10 and 82. Station 82 generally has  
274 lower concentrations of Mn and Al (by ~0.2 nM Mn and up to 5 nM Al) than Station 10. To  
275 calculate influx, the average Al and Mn concentrations over each density interval for station 82  
276 and 10 were calculated and multiplied by transport rate. Error was determined using the  
277 combined analytical error (1SD) of the measurements used to calculate the average.

#### 278 2.1.2 Outflow

279 The depth-weighted average concentrations of DAl, TDAI, DMn, and TDMn over each density  
280 interval for each strait/station were multiplied by water transport rate (Eq. 1). The chemical  
281 distributions at station 77 (Vitiav Strait), station 60 (St. George's Channel), and station 42  
282 (Solomon Strait) are assumed to be representative of the water leaving the Solomon Sea. Station  
283 60 is not located within St. George's Channel; however we assume that it is representative of  
284 water leaving the Solomon Sea via this channel for two reasons. First, the temperature-salinity  
285 profile of other stations sampled using the standard CTD rosette in Saint George's Channel are  
286 similar to Station 60 (Germineaud et al., 2016). Second, ADCP data at station 60 show that  
287 currents flow toward both Saint George's Channel and the Solomon Strait, meaning that at least  
288 some portion of the water that flows across station 60 must ultimately be directed out of the  
289 Solomon Sea (Germineaud et al., 2016).

290 **3. Results**

291 DAI, TDAI, DMn, and TDMn in and around the Solomon Sea from the 2012 PANDORA cruise  
 292 are shown versus potential density in Figures 2-5, and versus depth (supplemental Fig. S2-S5).  
 293 Here we define the surface layer as being from the surface ( $\sim 21\sigma_\theta$ ) to  $24\sigma_\theta$  (0-  $\sim 150$  m), the  
 294 thermocline layer from  $\sim 150$ -  $\sim 450$ m ( $24$ - $26.9\sigma_\theta$ ), and deep waters at depths  $>\sim 450$ m- $1300$ m  
 295 ( $>26.9\sigma_\theta$ ). Each plot includes a profile of the average of stations 10 and 82, which are  
 296 considered to be representative of water entering the Solomon Sea at its southern entrance.  
 297 However, we note that these profiles are not representative of all surface water entering the  
 298 Solomon Sea, as there is additional inflow through the Solomon Islands or through the Solomon  
 299 Strait (e.g., Hristova and Kessler, 2012; Albery et al., 2019).

**Table 1a.** Depth-weighted average DAI and TDAI concentrations. Values are calculated by integrating concentration data over the depth interval corresponding to the potential density range of each station. Reported error represents one standard deviation calculated from the analytical error of each measurement.

		Surface layer Surf – $24\sigma_\theta$		Thermocline layer /NGCU $24$ – $26.9\sigma_\theta$		Deep layer $<26.9\sigma_\theta$	
	Station	DAI (nM)	TDAI (nM)	DAI (nM)	TDAI (nM)	DAI (nM)	TDAI (nM)
Inflow	82	12.7 $\pm$ 0.6	12.7 $\pm$ 0.6	6.2 $\pm$ 0.8	7.8 $\pm$ 0.8	6.8 $\pm$ 0.8	7.3 $\pm$ 0.8
	10	10.4 $\pm$ 0.7	10.1 $\pm$ 0.8	5.8 $\pm$ 0.8	5.1 $\pm$ 0.8	8.0 $\pm$ 0.9	7.5 $\pm$ 0.9
	<b>Average</b>	<b>11.4<math>\pm</math>1.3</b>	<b>11.2<math>\pm</math>1.5</b>	<b>6.0<math>\pm</math>0.8</b>	<b>6.5<math>\pm</math>1.5</b>	<b>7.5<math>\pm</math>0.7</b>	<b>7.4<math>\pm</math>0.7</b>
NGCU Flow path	34	12.5 $\pm$ 0.6	12.5 $\pm$ 0.6	10.5 $\pm$ 0.6	11.5 $\pm$ 0.5		
	39	13.3 $\pm$ 0.5	13.2 $\pm$ 0.5	6.5 $\pm$ 0.8	6.4 $\pm$ 0.8	8.3 $\pm$ 0.7	7.9 $\pm$ 0.7
	71	12.5 $\pm$ 0.8	12.6 $\pm$ 0.8	6.0 $\pm$ 1.3	8.0 $\pm$ 1.3	6.0 $\pm$ 1.4	9.6 $\pm$ 1.4
Outflow/ Straits	77	15.5 $\pm$ 0.7	19.1 $\pm$ 0.8	9.0 $\pm$ 0.7	10.8 $\pm$ 0.5	8.1 $\pm$ 0.8	11.5 $\pm$ 0.8
	42	11.0 $\pm$ 0.7	13.0 $\pm$ 0.7	8.9 $\pm$ 0.7	9.5 $\pm$ 0.7	9.3 $\pm$ 0.7	12.9 $\pm$ 0.8
	60	12.3 $\pm$ 0.7	12.3 $\pm$ 0.7	6.6 $\pm$ 0.7	7.5 $\pm$ 0.7	6.1 $\pm$ 0.7	9.3 $\pm$ 0.7
Outside of Solomon Sea	43	6.3 $\pm$ 0.5	5.7 $\pm$ 0.7	6.0 $\pm$ 1.0	4.7 $\pm$ 1.1	5.9 $\pm$ 1.0	6.0 $\pm$ 0.7
	13	9.6 $\pm$ 1.0	9.2 $\pm$ 0.9	5.6 $\pm$ 1.2	5.6 $\pm$ 1.2	8.6 $\pm$ 1.1	7.6 $\pm$ 1.1
	21	14.4 $\pm$ 0.7	23.5 $\pm$ 0.8	9.4 $\pm$ 0.8	15.0 $\pm$ 1.1	10.2 $\pm$ 0.7	15.3 $\pm$ 1.1
	4	11.9 $\pm$ 0.5	11.5 $\pm$ 0.5	10.2 $\pm$ 0.8	10.1 $\pm$ 0.8	7.7 $\pm$ 0.8	8.8 $\pm$ 0.9

300

301

**Table 1b.** Depth-weighted average DMn and TDMn concentrations. Values are calculated by integrating concentration data over the depth interval corresponding to the potential density range of each station. Reported error represents one standard deviation calculated from the analytical error of each measurement.

	Station	Surface layer Surf – 24 $\sigma_\theta$		Thermocline layer/NGCU 24 – 26.9 $\sigma_\theta$		Deep layer <26.9 $\sigma_\theta$	
		DMn (nM)	TDMn (nM)	DMn (nM)	TDMn (nM)	DMn (nM)	TDMn (nM)
Inflow	82	1.52±0.11	1.61±0.11	0.27±0.02	0.41±0.03	0.23±0.02	0.41±0.03
	10	1.21±0.11	1.30±0.09	0.27±0.02	0.39±0.02	0.37±0.02	0.56±0.05
	<b>Average</b>	<b>1.32±0.22</b>	<b>1.43±0.19</b>	<b>0.27±0.02</b>	<b>0.40±0.02</b>	<b>0.30±0.07</b>	<b>0.48±0.07</b>
NGCU Flow path	34	0.59±0.12	0.84±0.06	0.30±0.04	0.48±0.04	0.27±0.04	0.53±0.05
	39	1.32±0.09	1.51±0.10	0.25±0.05	0.43±0.05	0.27±0.04	0.53±0.05
	71	1.05±0.06	1.15±0.06	0.24±0.03	0.40±0.04	0.34±0.04	0.63±0.06
Outflow/ Straits	77	1.22±0.10	1.45±0.12	0.26±0.01	0.49±0.02	0.51±0.04	0.88±0.07
	42	0.77±0.06	1.07±0.09	0.27±0.05	0.49±0.05	0.46±0.06	0.81±0.06
	60	1.26±0.10	1.35±0.11	0.28±0.02	0.44±0.03	0.43±0.03	0.74±0.06
Outside of Solomon Sea	43	0.72±0.05	0.79±0.05	0.32±0.14	0.42±0.04	0.33±0.03	0.50±0.05
	13	0.70±0.05	0.80±0.06	0.29±0.10	0.40±0.09	0.39±0.08	0.60±0.05
	21	0.93±0.07	1.38±0.11	0.31±0.09	0.56±0.04	0.38±0.08	0.68±0.05
	4	1.54±0.09	1.58±0.09	0.38±0.02	0.54±0.05	0.36±0.02	0.63±0.06

302

303 In the surface layer, average DA1 and TDA1 inflowing water are  $11.4 \pm 1.4$  nM and  $11.2 \pm 1.3$   
304 nM, respectively. Within the Solomon Sea (stations 34, 39, 71) and in St. George’s Channel  
305 (station 60), average DA1 and TDA1 in the surface layer are ~1-2 nM greater than in the  
306 inflowing water. The Solomon Strait (station 42) shows a decrease in DA1 (~0.5 nM), but an  
307 enrichment of ~1nM in TDA1. By contrast the Vitiav Strait (station 77), shows a much greater  
308 enrichment in both DA1 and TDA1 (~4 nM and ~8 nM, respectively). Outside of the Solomon  
309 Sea to the north and northeast (stations 13 and 43; Figs. 2,3 j,k) DA1 and TDA1 are ~2-5 nM  
310 lower than the waters entering the Solomon Sea. Station 21, which is just outside of the eastern  
311 opening of the Solomon Sea and south of the Solomon Islands, is fed by waters from north of the  
312 Solomon Islands (e.g., from station 13) that flows through gaps in the islands, resulting in  
313 average concentrations at station 21 being enriched by 5 nM for DA1 and 13 nM for TDA1  
314 relative to their concentrations at station 13.



315 In the thermocline layer which, within the Solomon Sea, is largely made up of the NGCU (~150-  
316 450 m; 24-26.9  $\sigma_\theta$ ), DA1 and TDA1 generally decrease from surface concentrations to lower  
317 values, often reaching mid-depth minima at different depths for different stations (Fig. 2 and Fig.  
318 S2). Over this density range, the inflowing waters have depth-weighted average DA1 and TDA1  
319 concentrations of  $6.0 \pm 0.8$  nM, and  $6.5 \pm 1.5$  nM, respectively. Along the flow path of the  
320 NGCU (stations 39 and 71), concentrations remain roughly constant relative to inflow, with  
321 slight enrichments of DA1 (~0.5 nM) at station 39 and TDA1 (~1.6 nM) at station 71. In the exit  
322 straits (stations 42, 60, and 77) DA1 and TDA1 are enriched relative to the inflow by ~0.65 nM –  
323 4 nM. To the north and northeast of the Solomon Sea (station 13 and 43) DA1 is similar to the  
324 inflowing water, while TDA1 is less at station 13 (~1 nM) and station 43 (~2 nM; however, it  
325 should be noted that DA1 at station 43 exceeds TDA1, suggesting that these samples may be  
326 slightly contaminated). Stations 4 and 21, which are close to local bathymetry (e.g., sills, straits)  
327 are enriched in DA1 at both stations by ~4 nM, and in TDA1 by ~4 nM and ~8 nM at station 4  
328 and 21, respectively.

329 In the deep layer (>450 m; >26.9  $\sigma_\theta$ ) the depth-weighted average inflowing DA1 is  $7.5 \pm 0.7$  nM,  
330 and TDA1 is  $7.4 \pm 0.7$  nM. Within the basin (stations 39 and 71), in the Vitiaz Strait (station 77),  
331 as well as outside the Solomon Sea (station 13), depth-weighted average DA1 concentrations are  
332 within the observed variability of the inflowing water. There is slight enrichment in DA1 (~2-3  
333 nM) in the Solomon Strait (station 42) and near the Solomon Islands (station 21). There are  
334 small (2-3 nM) enrichments of TDA1 within the basin at station 71 and in St. George's channel at  
335 station 60, and larger enrichments relative to the inflow (4-5 nM) in Vitiaz (station 77) and  
336 Solomon (station 42) Straits, as well ~8 nM enrichment at station 21 on the eastern edge of the  
337 basin, again reflecting the proximity to local bathymetry. Northeast of the Solomon Sea (station  
338 43), both DA1 and TDA1 are depleted by ~1 nM, relative to the waters flowing into the Solomon  
339 Sea.

340 Mn has a scavenged distribution at all stations, with the highest concentrations at the surface and  
341 generally decreasing with depth. From the surface to  $24\sigma_\theta$ , the depth-weighted average  
342 concentration of inflowing waters for DMn is  $1.32 \pm 0.22$  nM, while TDMn is  $1.43 \pm 0.19$  nM.  
343 Within the Solomon Sea, DMn and TDMn at most stations do not vary from these inflow values  
344 (stations 39, 60, 77), or are depleted relative to the inflowing waters by  $\sim 0.3 - 0.7$  nM along the  
345 flow path of the NGCU (stations 34, 42). Station 21 is also depleted in DMn by  $\sim 0.4$  nM relative  
346 to inflowing waters. Outside the Solomon Sea (stations 13, 43), DMn and TDMn are depleted by  
347  $\sim 0.6$  nM relative to inflowing water, while south of the Solomon Sea at station 4, DMn and  
348 TDMn concentrations are  $\sim 0.2$  nM higher than the waters flowing into the Solomon Sea.

349 Over  $24-26.9 \sigma_\theta$ , the depth-weighted average DMn of inflowing water is  $0.27 \pm 0.02$  nM and  
350 TDMn is  $0.40 \pm 0.02$  nM. In this density interval, most stations have DMn and TDMn  
351 concentrations that are within the variability of the inflow. There are a few stations where there  
352 is enrichment ( $\sim 0.1$  nM) of TDMn – along the flow path of the NGCU at station 34, in the Vitiaz  
353 (station 77) and Solomon (station 42) Straits. TDMn is enriched  $\sim 0.2$  nM near the Solomon  
354 Islands (station 21). South of the Solomon Sea (station 4) DMn and TDMn are higher than those  
355 waters entering the Solomon Sea by  $\sim 0.1$  nM and  $\sim 0.2$  nM respectively.

356 In the deeper ocean ( $>450$ m;  $>26.9 \sigma_\theta$ ), on average, DMn and TDMn generally increase with  
357 depth at all stations. Below  $26.9 \sigma_\theta$ , the inflowing waters have a depth-weighted average DMn  
358 concentration of  $0.30 \pm 0.07$  nM and TDMn concentration of  $0.48 \pm 0.07$  nM. In the straits,  
359 (stations 77, 60, and 42), enrichments in DMn and TDMn relative to the inflow are on the order  
360 of  $0.1-0.2$  nM and  $0.3-0.4$  nM, respectively. Within the basin (stations 34, 39, 71) the average  
361 concentrations of DMn are generally similar to those in the inflow, while smaller enrichments  
362 ( $\sim 0.1$  nM) of TDMn are found at stations 4, 10, 13, 71, and of  $0.2$  nM at station 21.

363 **4. Discussion**

364 **4.1 Al and Mn enrichments within the Solomon Sea**

365 4.1.1 Surface Layer (surf -  $24\sigma_\theta$ )

366 Over this potential density interval, average Al and Mn concentrations are lowest in the surface  
367 ocean at the two stations (13 and 43) located in the westward flowing South Equatorial Current  
368 (SEC) north and east of the Solomon Islands just outside of the Solomon Sea, relative to  
369 concentrations elsewhere in the Solomon Sea basin. This must reflect their westward transport  
370 from the open ocean. This is consistent with the Al values observed at the eastern entrance of the  
371 Solomon Sea (station 10; Table 1a, Table S2). Within the Solomon Sea and the straits, average  
372 concentrations over this density interval tends to be higher.

373 The elevated surface concentrations (Table 1) that are observed in Mn and Al within the  
374 Solomon Sea could be derived from riverine, aeolian, or coastal/margin sources. Based on  
375 salinity, our data reveal no large inputs of fresh water to the Solomon Sea during this cruise and  
376 consequently no correlation between salinity and trace metals is observed. This means either that  
377 at the time of the cruise, trace metal inputs to the Solomon Sea via rivers were small or that trace  
378 metal inputs were large relative to freshwater input, which is more consistent with observations  
379 of high sediment loads, relative to fluvial discharge in this region (e.g., Milliman et al., 1999).  
380 Dust input to the Solomon Sea can be predicted using the MADCOW model (Measures and  
381 Brown, 1996) based on regional dust fluxes and empirical dust solubilities. Using a dust flux of  
382  $1.0 \text{ g m}^{-2} \text{ y}^{-1}$  to the Solomon Sea (Shank and Johansen, 2008), an empirical dust solubility of  
383 6.0% (Buck et. al., 2006), a residence time of surface water in the Solomon Sea of 0.6-2 months  
384 (estimated based on an average velocity of  $20\text{-}60 \text{ cm s}^{-1}$  over the  $\sim 1000 \text{ km}$  distance between the  
385 inflow and outflow, and consistent with literature estimates (Melet et al., 2011, Hristova and

386 Kessler, 2012; Alberty et al., 2019)) and a mixed layer depth <100 m (based the definition of de  
387 Boyer Montégut et al., 2004), it can be estimated that DA<sub>I</sub> added from dust deposition accounts  
388 for only 0.30 nM to 1.14 nM of the DA<sub>I</sub> added to the surface waters as they transit through the  
389 Solomon Sea which is only  $\sim 5.4\% \pm 2.5\%$  (1SD) of DA<sub>I</sub> present there. Thus, dust is a relatively  
390 small source of DA<sub>I</sub> to the waters in this region. A similar estimation for DMn can be made  
391 using a fractional solubility of Mn in dust of 45.1% from Buck et al. (2013), and a crustal  
392 abundance of Mn of 954 ppm from Taylor, (1964) to be consistent with the reference used by  
393 Measures and Brown (1996). We estimate that DMn added from dust deposition as the waters  
394 transit through the Solomon Sea to be only 0.01 nM to 0.05 nM or  $\sim 1.9\% \pm 0.9\%$  (1SD) of DMn  
395 present in the surface Solomon Sea.

396 Elevated Al and Mn concentrations in the surface ocean within the straits and Solomon Sea,  
397 relative to inflowing waters or stations outside the Solomon Sea, suggest that these elements  
398 become enriched when waters interact with local bathymetry as they enter the basin. The SEC  
399 transports surface waters into the Solomon Sea passing through both the Solomon Strait and  
400 other gaps in the Solomon archipelago ultimately exiting through the Vitiaz Strait (Cravatte et al.,  
401 2011; Hristova and Kessler, 2012). TDA<sub>I</sub> of the surface samples in both the Solomon Strait  
402 (station 42 –  $18.7 \pm 0.4$  nM) and Vitiaz Strait (station 77 –  $38.7 \pm 0.4$  nM) are enriched compared to  
403 DA<sub>I</sub> ( $13.5 \pm 0.3$  nM,  $28.7 \pm 0.4$  nM respectively) suggesting the input of sediments or rapid removal  
404 of DA<sub>I</sub> by scavenging. A similar but muted effect is seen for Mn at these stations. The high Mn  
405 (2.5 nM) and Al (>20 nM) in the surface waters that exit through the Vitiaz Strait (station 77)  
406 must result from scouring and entrainment of local sediments into the water column due to rapid  
407 geostrophic current velocities (20-60 cm/s; e.g. Hristova and Kessler 2012) coupled with the  
408 narrow strait. A maximum in Rare Earth Elements (REE), including dissolved Cerium (Ce), was  
409 also observed in the surface waters at station 77 during the PANDORA cruise (Pham et al.,  
410 2019). At the eastern end of the Solomon archipelago, where waters flow from the SEC (station  
411 13) through the islands to station 21, Mn and Al concentrations are also greater than those in the  
412 SEC (see results) reflecting input from the islands and the scouring of coastal sediments. This is

413 also largely consistent with enrichments in REEs observed during PANDORA (Pham et al.,  
414 2019). The surface water flowing through the Solomon Sea has a residence time of ~ 53-103  
415 days (Melet et al., 2011), so input and removal processes for Mn and Al must be both strong and  
416 rapid to produce the changes in concentrations observed here.

417 Using transport estimates reported in Germaineaud et al. (2016) and the average concentrations of  
418 metals at stations in/near the straits, we can estimate the fluxes entering the Solomon Sea from  
419 the southern entrance and exiting via the three straits. However, transport estimates  
420 (Germaineaud et al., 2016) are unbalanced with a transport entering the Solomon Sea via the  
421 southern entrance of  $3.3 \pm 0.4$  Sv, and exiting the Solomon Sea of  $6.9 \pm 0.6$  Sv ( $4.5 \pm 0.4$  Sv  
422 through the Vitiaz Strait and a combined  $2.4 \pm 0.3$  Sv through St. George's Channel, and the  
423 Solomon Strait). The missing flow likely enters through the gaps in the Solomon Islands. As a  
424 result, in the surface layer, our budget is unbalanced, and the larger exit fluxes reflect the  
425 differences in flow. Table 2 reports the flux in through the southern entrance and out through the  
426 straits. While we cannot calculate a balanced flux value for the inflow, the depth-weighted  
427 average concentrations at the exit straits all suggest that water leaving the Solomon Sea is within  
428 the variability of, or enriched in, Al and Mn relative to the inflowing surface layer (Table 1).

429 Trace metal fluxes based on transport in the surface layer are reported in Table 2. This budget  
430 does not consider diapycnal/vertical mixing between layers, because vertical mixing does not  
431 appear to be reflected in the chemical profiles that we see in Al and Mn in the upper NGCU.  
432 While diapycnal mixing in the Solomon Sea is important (Melet et al., 2011), based on the  
433 erosion of the salinity maximum in the thermocline between the entrance and the exit of the  
434 Solomon Sea and the salinity of the surface layer, we calculate that no more than 33% of water is  
435 mixed between our density intervals. Additionally, several water masses converge upon entrance  
436 into the Solomon Sea (e.g., Kessler et al., 2019) and there is evidence of vertical mixing due to  
437 internal tides in the region (e.g., Melet et al., 2011), making diapycnal mixing in the surface layer  
438 hard to resolve.

**Table 2:** Transport and trace metal flux estimates for the surface (surf-24) in the Solomon Sea. Transport estimates from Germaineud et al. (2016). Solomon Strait and St. George’s Channel transport are estimated based on total transit through the two outflow straits. Errors represent the combined error from the transport estimate and the analytical error (1 SD) of the average concentration.

Station	Transport (Sv)	DAI (mol/s)	TDAI (mol/s)	DMn (mol/s)	TDMn (mol/s)
Inflow	$3.3 \pm 0.4$	$38 \pm 6$	$37 \pm 7$	$4.4 \pm 0.9$	$4.71 \pm 0.8$
Vitiaz Strait (station 77)	$4.5 \pm 0.1$	$70 \pm 4$	$86 \pm 4$	$5.5 \pm 0.5$	$6.5 \pm 0.5$
Solomon Strait (station 42)	$1.2 \pm 0.3$	$13 \pm 3$	$15.6 \pm 4.0$	$0.9 \pm 0.2$	$1.3 \pm 0.3$
St. George’s Channel (station 60)	$1.2 \pm 0.3$	$15 \pm 4$	$14.7 \pm 3.8$	$1.5 \pm 0.4$	$1.6 \pm 0.4$
Total Outflow	$6.9 \pm 0.3$	$98 \pm 11$	$116 \pm 12$	$7.9 \pm 1.1$	$9.4 \pm 1.3$

440

441

#### 442 4.1.2 Thermocline layer – ~150-450 m and 24-26.9 $\sigma_\theta$

443 The water between ~150-450 m and 24-26.9  $\sigma_\theta$  is dominated by the core of NGCU, which  
 444 originates from the south and east of the Solomon Sea (see section 1.1). At this depth/density  
 445 range, dissolved and total dissolvable Al and Mn are lower than in the surface ocean (see Table 1  
 446 and results), however there are enrichments in DAI, TDAI, and TDMn (but not DMn) relative to  
 447 the water flowing into the Solomon Sea (Sta. 10 and 82). The pattern of enrichments is similar,  
 448 in part, to those in the surface layer with enrichments in DAI, TDAI, and TDMn in the Solomon  
 449 (station 42) and Vitiaz (station 77) straits. At station 21 where water flows roughly from station  
 450 13 to 21 through the gaps in the Solomon Islands (Hristova and Kessler, 2012) and near a  
 451 shallow sill, enrichments in DAI, TDAI, DMn, and TDMn are observed (Figures 2-5, k and l).

452 Sampling during PANDORA included measurements of Rare Earth Elements, and our data is  
453 consistent with increases in dissolved Lanthanum (La), Neodymium (Nd), Europium (Eu), and  
454 Ytterbium (Yb) between stations 13 and 21, reported by Pham et al. (2019). Dissolved Ce and  
455 the Ce anomaly are not modified between stations (Pham et al., 2019), which suggests that the  
456 water mass is the same between the two stations, but that particle inputs are recent and  
457 modifications do not cause changes in dissolved Ce, because it is insoluble. The best explanation  
458 for these observations is sediment resuspension which is supported by larger enrichments (~9  
459 nM TDAI, 0.2 nM TDMn) in total dissolvable metals versus dissolved metals (~4 nM DAi, ~0  
460 nM DMn). Coincident enrichment of Mn and Al also occurs in the Vitiaz Strait (station 77),  
461 similarly suggesting sediment resuspension, rather than reductive release from shelf sediments or  
462 hydrothermal input at these stations, as these other two processes would impact Mn distributions  
463 to a greater extent than Al distributions. This is also consistent with Ce anomaly data, which  
464 shows decreasing solubility, rather than remineralization in the Vitiaz Strait (Pham et al., 2019).  
465 Physical resuspension/non-reductive dissolution is implicated for the enrichment of Fe in the  
466 Vitiaz Strait and the NICU based on Fe isotope measurements (Labatut et al., 2014). These Fe  
467 enrichments reflect particulate iron transported from the continent across shelves and slopes,  
468 followed by release of DFe from suspended particles (Labatut et al., 2014). This has also been  
469 observed for Al and Mn in other regions. Al remobilized from benthic nepheloid layers is an  
470 important source for Al in the deep waters of the North Pacific (Moran and Moore, 1991).  
471 Lateral transport of Mn remobilized from shelves has been observed off the coast of California  
472 (Martin et al., 1987) who show that major sub-surface maxima and minima in the Mn  
473 distributions are controlled primarily by sedimentary release combined with water mass  
474 movement and physical mixing, rather than through scavenging and remineralization processes.

475 The NGCU is expected to flow from station 34 to 39 and then to 71 after which it bifurcates,  
476 going WNW to the Vitiaz strait (station 77) and NE to station 60 and then on to the Solomon  
477 strait (station 42) (Fig. 1). Two of the stations along the predicted flow path of the NGCU (34  
478 and 71) show enrichments in DAi, TDAi, and TDMn that exceed the variability of the average

479 inflow profile, while station 39 shows no enrichments in either Al or Mn (see Table 1 and  
480 results). At station 71, the coherence between DAl and TDAI provides confidence in sample  
481 quality and thus the lack of a mid-depth enrichment at station 39 indicates that this station is  
482 either not in the NGCU, or that local trace metal input and removal are highly dynamic and  
483 variable. Based on transport and current speeds, the NGCU/NBCU is estimated to take 2-4  
484 months to transit through the Solomon Sea, which is also consistent with model estimates of  
485 residence times (Melet et al., 2011). This is much shorter than reported residence times of Al in  
486 the open ocean. Because this region has large coastal influence, it is possible that input and  
487 removal of Al are rapid, and riverine inputs and coastal sediments must release and scavenge Al  
488 on shorter timescales than the residence time of NGCU waters in the Solomon Sea. If station 34  
489 is not in the flow path of the NGCU, then the enrichments seen at station 39 are local. However,  
490 if station 39 is not in the flow path of the NGCU, then the enrichments at station 71 might be  
491 sourced from the upstream waters coming from station 34. In either case, the small increases in  
492 TDAI without enrichments in DAl and Mn at station 60 may be sourced from station 71.

493 In the thermocline layer, observations show that water transport into and out of the Solomon Sea  
494 was roughly equal at the time of the PANDORA cruise with transport into the Solomon Sea at its  
495 southern entrance  $\approx 23.6 \pm 0.8$  Sv, and transport out of the Solomon Sea through the exit straits  
496  $\approx 22.8 \pm 1.0$  Sv (Germineaud et al., 2016). This allows us to construct a steady state budget with  
497 regard to transport over this density interval. Despite strong seasonal and interannual variability  
498 in flow through the Solomon Sea, (e.g., Germaineaud et al., 2016; Albery et al., 2019), estimates  
499 of the transport of the EUC (e.g., Grenier et al., 2011; Lindstrom et al., 1987; Tsuchiya et al.,  
500 1989) are similar to the Solomon Sea transport over this density interval (22-23 Sv) observed by  
501 Germaineaud et al. (2016) during PANDORA. In our steady state model, chemical influx is thus  
502 calculated by multiplying the depth-weighted average inflow profile for the Solomon Sea by  
503  $22.8 \pm 1.0$  Sv. We also consider that DAl, TDAI, DMn, and TDMn distributions in the Vitiaz  
504 Strait (station 77), St. George's Channel (station 60), and Solomon Strait (station 42) are



505 representative of the water leaving the Solomon Sea via the NGCU, SGU, and NICU,  
 506 respectively.

507 The inflow, outflow, and EUC trace metal fluxes are reported in Table 3.

**Table 3.** Transport and trace metal flux estimates for the thermocline layer (24-26.9 $\sigma_\theta$ ) in the Solomon Sea. Transport estimates are from Germaineaud et al. (2016). Solomon Strait and St. George's Channel transport are estimated based on total transit through the two outflow straits. Errors represent the combined uncertainty from the transport estimate and the analytical error (1 SD) of the average concentration.

	Transport (Sv)	Dal mols/s	TDAI mols/s	DMn mols/s	TDMn mols/s
Inflow* (mol s <sup>-1</sup> )	22.8 ± 1.0	136 ± 19	147 ± 35	6.1 ± 0.5	9.1 ± 0.6
Vitiaz Strait (station 77)	10.3 ± 0.3	93 ± 8	111 ± 5	2.7 ± 0.1	5.0 ± 0.3
Solomon Strait (station 42)	6.25 ± 0.4	56 ± 6	59 ± 6	1.7 ± 0.3	3.1 ± 0.4
St. George's Channel (station 60)	6.25 ± 0.5	42 ± 5	47 ± 4	1.7 ± 0.2	2.7 ± 0.3
Outflow (mol s <sup>-1</sup> )	22.8 ± 1.0	190 ± 19	217 ± 16	6.1 ± 0.6	10.8 ± 1.0

508

509 These data show that at the time of the PANDORA cruise, fluxes of DAL, TDAI, and TDMn out  
 510 of the Solomon Sea in the thermocline waters were only slightly higher (8-90 mol/s DAL, 7-130  
 511 mol/s TDAI, 0.3-2.4 mol/s TDMn) than fluxes into the Solomon Sea, and that DMn fluxes  
 512 remained constant through the basin.

513 4.1.3 Deep layer – 450-1400 m;  $>26.9 \sigma_\theta$

514 In the deeper ocean (450m – 1300m;  $26.9 \sigma_\theta - \sim 27.5 \sigma_\theta$ ) Al and Mn generally show enrichment  
515 within the straits or near local bathymetry, which is similar to what was observed in the  
516 thermocline layer, with some exceptions. The enrichments in TDAI and TDMn relative to  
517 background concentrations that are observed in the Vitiaz and Solomon Straits (stations 77 and  
518 42) reflect the proximity of these stations to local bathymetry, combined with flow through these  
519 straits by the NGCU (station 77) and NICU (station 42). Similarly at station 21, increases in  
520 DAI, TDAI, and TDMn relative to concentrations at station 13 reflect enrichments due to  
521 scouring as the SEC flows through the Solomon Islands.

522 Other factors, such as accumulation of sinking particles may be responsible for the enrichments  
523 in Mn and Al at stations 39, 71, and 60, which lie deep within the Solomon Sea and are isolated  
524 from local features. The Woodlark Rise, extending 250 km NE from the Woodlark Island  
525 Archipelago to within  $\sim 60$  km from the Solomon Archipelago, is a ridge line of bathymetric  
526 highs that reach  $\leq 1000$ m with gaps between highs reaching  $\sim 1500$ m. This feature creates a semi-  
527 enclosed basin below  $\sim 1000$  m that encompasses stations 71 and 60 in the NE Solomon Sea.  
528 Below 400m, the NGCU (Alberty et al., 2019) transits from the Coral Sea and flows around the  
529 Louisiade Archipelago and then around, through, and/or over the Woodlark Rise; below 1000 m  
530 it likely passes through the channel between the Woodlark Rise and the Solomon Islands (Fig.  
531 1b). At stations 42 and 60, enrichments in TDAI and TDMn, the HCl-labile portion of the  
532 particulate fraction, likely represent sinking particles accumulating along the flow path of the  
533 NGCU/NBCU and within the semi-enclosed basin due to longer residence time for waters there.  
534 The residence time of water in the basin between  $\sim 450$  and  $\sim 1400$ m is estimated to be  $<1$  year  
535 based on models (Melet et al., 2011) or transport estimates, however transport (and current  
536 speed) significantly decreases with depth below 450m (Alberty et al., 2019; Gasparin et al.,  
537 2012) resulting in increased residence times with depth.

538 The relative increases in TDAI and TDMn also arise from the scavenging of dissolved phases  
539 sourced along the flow path or from particles resuspended as water flows over the Woodlark rise  
540 and other bathymetry. Through the Vitiaz Strait (station 77), there is likely sediment  
541 resuspension from the bottom and walls of the channel ( $\sim 1100 \text{ m}/27.4 \sigma_\theta$ ) as water passes  
542 through. The larger enrichments in the exit straits may also be due to accumulation of sinking  
543 particles, or other local, shorter-lived phenomena (e.g., increased river runoff), though we do not  
544 have enough information to say this definitively. It is possible that at these deeper depths,  
545 especially through the Solomon Strait (station 42), decreased current speeds lessen the likelihood  
546 of scouring and sediment resuspension, supporting a role for sinking particles from shallow  
547 sources. Additional measurements in this region would help better constrain this hypothesis.

548 The straits in the Solomon Sea also exhibit increases in DMn with depth, which, in the deep  
549 layer, generally indicates recent inputs from sedimentary and/or hydrothermal sources but can  
550 also be associated with oxygen deficient zones. Prior to reaching the Woodlark Rise, within the  
551 Woodlark basin, hydrothermal activity is present at  $>2500 \text{ m}$  (Laurila et al., 2012) with  
552 shallower hydrothermal activity inferred at Kana Keoki seamount at  $650 \text{ m}$  near the Solomon  
553 Archipelago (InterRidge Database: <https://vents-data.interridge.org/>). These are unlikely to be  
554 the source of the Mn enrichments between  $700$  and  $1350 \text{ m}$ , however. Given the highly tectonic  
555 and magmatic character of the region, hydrothermal hot springs likely exist throughout the basin.  
556 Diffusion from or resuspension of sediments are also possible source mechanisms for DMn  
557 whose input coincides with transport through and along the Woodlark Rise. Dissolved oxygen  
558 remains relatively elevated throughout the basin at these depths, suggesting that particle  
559 remineralization does not play a large role in maintaining DMn levels. This is supported by  
560 dissolved Ce concentrations (Pham et al., 2019), which decrease as water flows through the  
561 basin, and Ce anomalies in the deeper ocean that do not indicate any shifts towards either  
562 remineralization or increased solubility due to changes in redox chemistry. The increase in DMn  
563 concentrations between stations 71 and 60 versus those in the straits suggest that sediments may  
564 be the predominant sources of DMn in the regional deep layer. The absence of an enrichment in

565 DMn, DA1, and TDA1 at station 39 (and small TDMn enrichment) suggests that there is little to  
566 no Mn input as the NGCU transits through and around bathymetry prior to reaching station 39 at  
567 these depths. While it is possible that the NGCU is bathymetrically steered away from station  
568 39, it seems more likely that Mn and/or Al are added after passing this station. The presence of  
569 DMn at this station suggests that the TDMn is sourced at depth from the oxidation and  
570 scavenging of DMn. Station 21 also shows enrichments in TDMn, TDA1, and DA1 relative to  
571 stations outside of the Solomon Sea suggesting the accumulation of dissolved metals and  
572 sediments as water flows through the Solomon Archipelago. While various small enrichments  
573 are observed at stations outside of the Solomon Sea, it is not possible to evaluate background  
574 values for these stations. However, we do note that the SEC flows past many shallow seamounts  
575 en route to the Solomon Sea.

576 Estimated fluxes of trace metals in the deep layer are determined based on transport estimates for  
577 the PANDORA cruise calculated by Germaineaud et al. (2016) and are reported in Table 4.  
578 Because there is less mixing deeper in the ocean, transport estimates are more consistent between  
579 the inflow ( $9.3 \pm 1.4$  Sv) and outflow ( $8.4 \pm 2.6$  Sv) than they are in the surface layer, but there are  
580 still large uncertainties on transport estimates deeper in the water column, as well as a slight  
581 imbalance between inflowing and outflowing water transport. Fluxes reported here for total  
582 outflow show that trace metal modifications are minimal relative to inflowing water, despite  
583 regions of local enrichment observed in profile data.

584

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**Table 4:** Transport and trace metal flux estimates for the deep layer ( $>26.9\sigma_\theta$ ) in the Solomon Sea. Transport estimates from Germaineaud et al. (2016). Solomon Strait and St. George's Channel transport are estimated based on total transit through the two outflow straits. The combined error from the transport estimate and the analytical error (1 SD) of the average concentration.

Station	Transport (Sv)	DAI (mol/s)	TDAI (mol/s)	DMn (mol/s)	TDMn (mol/s)
Inflow	9.3 ± 1.4	69.6 ± 12.1	68.6±12.0	2.76±0.78	4.51±0.96
Vitiaz Strait (station 77)	4.6± 0.2	37.3 ± 4.0	53.0 ± 4.2	2.33 ± 0.20	4.05 ± 0.37
Solomon Strait (station 42)	1.9 ± 1.2	17.7 ±11.6	24.5 ± 15.5	0.87 ±0.56	1.54 ±0.98
St. George's Channel (station 60)	1.9 ± 1.2	11.6 ±7.5	18.9 ±12.0	0.81 ±0.51	1.40 ±0.89
Total Outflow	8.4 ± 2.6	66.61 ± 22.7	96.3 ±31.7	4.01 ±1.27	6.99 ±2.24

585

586

#### 587 ***4.2 Constraining the Solomon Sea Flux to the EUC***

588 The EUC is largely composed of water originating from the NGCU/thermocline waters (24-26.9  
589  $\sigma_\theta$ ), and so we can compare the flux of trace metals out of the Solomon Sea (Table 3) in this  
590 layer to the flux of trace metals in the EUC over the same density interval by using average DAI,  
591 TDAI, DMn, and TDMn concentrations from the EUC collected at 0°, 156 °E by Slemmons et al.  
592 (2010; Station 22). At this longitude, water exiting the Solomon Sea would have been entrained  
593 in the EUC. These measurements were collected six years before the PANDORA cruise, but  
594 during the same season, and in a similar ENSO phase. The implicit assumption in the  
595 comparison of flux out of the Solomon Sea and the flux into the EUC is that everything leaving  
596 the Solomon Sea at that depth range enters the EUC, as shown in Fig. 6. This is clearly not the  
597 case, but this assumption establishes an upper bound for trace metals contributed from the  
598 Solomon Sea to the EUC. For flux estimates several additional assumptions are made: the  
599 Solomon Sea is in steady state and not temporally variable; stations in the straits are  
600 representative of water leaving the Solomon Sea; and that the two profiles used for inflow waters

601 are, on average, representative water entering the Solomon Sea. The trace metal fluxes of the  
 602 Solomon Sea Inflow, Outflow, and flux at the EUC are shown in Table 5.

**Table 5.** Average metal fluxes into and out of the Solomon Sea at  $24-26.9\sigma_{\theta}$  compared to metal fluxes in the EUC  $156^{\circ}\text{E}$ . This assumes that transport in and out of the Solomon Sea is  $22.8 \text{ Sv} \pm 1.0 \text{ Sv}$ . Errors are calculated using uncertainty reported on transport estimates (1SD) by Germaineaud et al. (2016) and analytical error of the concentration data (1SD)

	DAI	TDAI	DMn	TDMn
Inflow ( $\text{mol s}^{-1}$ )	$136 \pm 19$	$147 \pm 35$	$6.1 \pm 0.5$	$9.1 \pm 0.6$
Outflow ( $\text{mol s}^{-1}$ )	$190 \pm 19$	$217 \pm 16$	$6.1 \pm 0.6$	$10.8 \pm 1.0$
In EUC ( $\text{mol s}^{-1}$ )	$160 \pm 9$	$177 \pm 10$	$7.8 \pm 0.4$	$17 \pm 0.9$

603

604 4.2.1 Sources of water to the EUC

605 It is important to note that the EUC does not receive its water solely from the Solomon Sea, and  
 606 the breakdown of how much water comes from the Solomon Sea versus from other Southern and  
 607 Northern Hemisphere sources is still unclear. Hydrographic parameters measured during the  
 608 Western Equatorial Pacific Ocean Study (WEPOCS, 1985/1986) (e.g., Lindstrom et al., 1987;  
 609 Tsuchiya et al., 1989) show the EUC was fed predominantly by water from the Southern  
 610 Hemisphere with  $\sim 2/3$  from southern low latitude western boundary currents, including the  
 611 NGCU (Tsuchiya et al., 1989) and  $\sim 1/4$  of the water originating in the Northern Hemisphere  
 612 (Lindstrom et al., 1987; Tsuchiya et al., 1989). However, this study also observed a seasonally  
 613 variable NGCU, including one season in which it flowed at the same rate as the EUC. Since then,  
 614 other studies have investigated the relative importance of water from northern and southern  
 615 sources and have come to differing conclusions about the proportion of water from the north and  
 616 south. Grenier et al. (2011) estimate about 58% of the water in the EUC at  $156^{\circ}\text{W}$  passed  
 617 through the Solomon Sea, and about 33% comes from the Mindanao Current in the north, with

618 the remainder coming from other sources south of the EUC. A modeling study by Izumo et al.  
619 (2002) indicates roughly equal contributions from the Northern and Southern Hemispheres,  
620 while other studies suggest the dominance of a southern source (Liu and Huang, 1998). Most  
621 recently, biogeochemical tracer data indicate that the nutrients in the EUC are primarily derived  
622 from Southern Hemisphere water: based on isotopic tracers ( $^{15}\text{N}$  and  $^{18}\text{O}$  measured in nitrate) and  
623 oxygen measurements combined with the nutrient data (silicic acid and nitrate), the fraction of  
624 water in the EUC derived from the Mindanao Current (in the Northern Hemisphere) is estimated  
625 to be much smaller than that from the Southern Hemisphere (Lehmann et al., 2018).

626 The relative contributions of trace metals from the Solomon Sea to the EUC trace metal pool can  
627 then be estimated for the different estimates of northern versus southern water contribution to the  
628 EUC (Table 6). Averaging these estimates, our data suggest that about 70% of the DA1, 80% of  
629 the TDA1, 50% of DMn, and 40% of the TDMn in the EUC must come from waters exiting the  
630 Solomon Sea. It is also important to note that there is seasonal variability in these estimates, and  
631 that as the EUC flows east, it entrains additional water, and the relative importance of the waters  
632 originally feeding the EUC diminishes during its eastward transit (Qin et al., 2015). Our results  
633 indicate that the Solomon Sea can supply a majority of the required Al to the EUC. However,  
634 relative to Al, there is proportionally less Mn in the EUC coming from the Solomon Sea,  
635 suggesting other sources to the EUC must be more enriched in Mn and have higher Mn/Al ratio.

636 Because there are other sources of water to the EUC, there are other potential sources of trace  
637 metals to the EUC that are not accounted for with these Solomon Sea data. Waters exiting the  
638 Solomon Sea through the Vitiaz Strait pass along the PNG coast/shelf and through the Bismark  
639 Sea. However Mn data collected at stations just beyond the Vitiaz Strait along the PNG coast by  
640 Slemons et al. (2010) are remarkably consistent with Mn concentrations reported here. By  
641 comparison Al concentrations along the coast vary greatly, especially in the surface, but are  
642 generally lower by  $\sim 2\text{-}5$  nM (and in the surface up to 35 nM) compared to the data for the  
643 Solomon Sea reported here. These findings indicate that the PNG coastline does not provide the

644 missing Mn and may be a sink for Al. This is consistent with the findings of Mackey et al.  
 645 (2002a) who show that while concentrations of Fe and Mn are high off the coast of PNG  
 646 especially near the outflow of the Sepik River, this riverine source of Mn and Fe to the Bismarck  
 647 Sea is insufficient to produce the concentrations of these elements observed in the EUC. Just  
 648 beyond the Solomon Strait, enrichments observed for Rare Earth Elements indicate hydrothermal  
 649 and/or lithogenic inputs to the waters along the flow path of the NICU (Behrens et al., 2020)  
 650 between the Solomon Sea and EUC, however there are no Al and Mn data in this region and  
 651 thus, while we might anticipate inputs of Al and Mn to the NICU, conclusions about their inputs  
 652 to the NICU are not possible. As noted above, the EUC is derived from waters originating both  
 653 from the south and north of the equator and the balance of Al and Mn required to balance the  
 654 trace metal budget of the EUC may have their source there.

**Table 6.** Contribution of the Solomon Sea contribution to EUC trace metal pool based on variations in source waters. The flux of each trace metal out of the Solomon Sea is multiplied by the percentage of water contributed by the Solomon Sea to the EUC at 156°E based on different studies.

Reference	% of EUC derived from Southern Hemisphere	Method of Estimate	% trace metals contributed to EUC based on magnitude of source			
			DAI	TDAI	DMn	TDMn
	100%	Upper Bound	119	123	79	64
Grenier et al., 2011 <sup>1</sup>	59%	Model	70	72	47	38
Tsuchiya et al., 1989	67%	WEPOCS	80	82	53	43
Izumo et al., 2002	52%	Model	62	64	41	33
Lehman et al., 2018 <sup>2</sup>	<70%	O <sub>2</sub> , Si, N isotopes	83	86	55	45
Qin et al., 2015 <sup>3</sup>	63%	Model	75	77	50	40
Average			74	76	49	40

<sup>1</sup> Fluxes are contribution from Solomon Sea, specifically, <sup>2</sup> Looks at upper and lower EUC, <sup>3</sup>40% Solomon Strait, 23% Vitiaz Strait at 165°E

655



656 **5. Conclusions**

657 Our data show that water exiting the Solomon Sea is important in supplying aluminum, and to a  
658 lesser degree, manganese, to the Equatorial Undercurrent. However, from a net budget  
659 perspective, the amount of Al and Mn enrichment that occurs within the basin is small, relative  
660 to the inflow concentrations, indicating that most of the Al and Mn was acquired prior to  
661 reaching the Solomon Sea or that inputs are approximately balanced by scavenging within the  
662 basin. This is also true for deeper water in the Solomon Sea. The trace metal pool in the surface  
663 layer does appear to be enriched relative to inflowing waters, but because of large seasonal  
664 variability and disparities in water transport between entrance and exit, more studies are needed  
665 to conclude this definitively.

666 Our work is consistent with previous studies and supports the idea that boundary exchange  
667 through sediment resuspension, non-reductive release of dissolved species from suspended  
668 particles, and scavenging onto these suspended particles are the dominant processes providing  
669 additional metals to the Solomon Sea (e.g., Lacan and Jeandel, 2005; Grenier et al., 2013;  
670 Labatut et al., 2014; Jeandel, 2016). These highly localized input processes indicate that a higher  
671 resolution study is required to better understand these boundary processes, and in particular, their  
672 potential to impact larger-scale cycling.

673 The importance of the Solomon Sea as a source of trace nutrients to the EUC is heavily  
674 influenced by the proportion of water in the EUC that is derived from the Southern Hemisphere.  
675 Improving our estimates of the EUC water mass breakdown from important regions of input in  
676 the Northern Hemisphere (e.g., North Equatorial Current, Mindanao Current) will be valuable in  
677 better constraining these fluxes. Higher sampling resolution (spatial and temporal) within the  
678 region, including within the EUC, at potential source regions south of the Solomon Sea  
679 (including near Vanuatu, and in the Coral Sea), and from the SEC will be important in  
680 constraining the impact of the waters passing through the Solomon Sea on the chemistry of the  
32

681 EUC. This increased resolution would allow for a more thorough understanding of trace metal  
682 and nutrient dynamics in the western Pacific and their impact on the HNLC eastern equatorial  
683 Pacific.

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697

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905 **Figure Captions**

906 **Fig. 1. a)** Sub-surface currents [dark blue; after Germaineaud et al. (2016)], rivers (blue text),  
907 straits (purple text) and potential point sources (yellow) to the Solomon Sea. These currents are:  
908 Equatorial Undercurrent (EUC); South Equatorial Current (SEC); New Guinea Coastal  
909 Undercurrent (NGCU); New Ireland Coastal Undercurrent (NICU); Saint George's Undercurrent  
910 (SGU); North Queensland Current (NQC); New Caledonia Jet (NCJ); North Vanuatu Jet (NVJ);  
911 East Australian Current (EAC)  
912 Red dots and numbers represent stations sampled for Al and Mn. Orange dot shows the  
913 location of station 22 from Slemons et al. (2010). **b)** Bathymetry of the Woodlark  
914 Basin and Trobriand Islands.

915 **Fig. 2.** Dissolved Al (DAI) profiles versus potential density from the PANDORA cruise. Light  
916 blue circles show measured DAI concentrations. Orange line represents average inflow DAI  
917 profile, while grey shading represents the bounds of the average profile. Green box represents the  
918 density interval over which budget of the thermocline waters is calculated. **(a–c)** waters that are  
919 located south of the Solomon Sea; **(d–f)** profiles found along the NGCU; **(g–i)** profiles that are at  
920 the exit straits of the Solomon Sea; **(j–l)** located outside the Solomon Sea.

921 **Fig. 3.** Total Dissolvable Al (TDAI) profiles versus potential density from the PANDORA  
922 cruise. Dark blue circles show measured TDAI concentrations. Orange line represents average  
923 inflow TDAI profile, while grey shading represents the range of inflow concentrations. Green  
924 box represents the density interval over which budget of the thermocline waters is calculated. **(a–**  
925 **c)** waters that are located south of the Solomon Sea; **(d–f)** profiles found along the NGCU; **(g–i)**  
926 profiles that are at the exit straits of the Solomon Sea; **(j–l)** located outside the Solomon Sea.

927 **Fig. 4.** Dissolved Mn (DMn) profiles versus potential density from the PANDORA cruise. Pink  
928 diamonds show measured DMn concentrations. Orange line represents average inflow DMn  
929 profile, while grey shading represents the range of inflow concentrations. Green box represents  
930 the density interval over which budget of the thermocline waters is calculated. (a–c) waters that  
931 are located south of the Solomon Sea; (d–f) profiles found along the NGCU; (g–i) profiles that  
932 are at the exit straits of the Solomon Sea; (j–l) located outside the Solomon Sea.

933 **Fig. 5** Total Dissolvable Mn (TDMn) profiles versus potential density from the PANDORA  
934 cruise. Red diamonds show measured TDMn concentrations. Orange line represents average  
935 inflow TDMn profile, while grey shading represents the range of inflow concentrations. Green  
936 box represents the density interval over which the mass balance is calculated. (a–c) waters that  
937 are located south of the Solomon Sea; (d–f) profiles found along the NGCU; (g–i) profiles that  
938 are at the exit straits of the Solomon Sea; (j–l) located outside the Solomon Sea.

939 **Fig. 6.** Budget for thermocline waters ( $24\text{--}26.9 \sigma_\theta$ ), showing the flux of DA1, TDA1, DMn,  
940 TDMn at the inflow, the outflow via currents (NGCU, NICU, and SGU), and the flux out of the  
941 EUC at  $156^\circ\text{E}$ , as well as the average concentration of the Solomon Sea, calculated from stations  
942 most representative of the Solomon Sea. Red dots represent stations used to calculate  
943 concentrations at each exit strait over the potential density range of the EUC

944

945 **Supplemental Fig. 1.** Implied labile particle concentrations of aluminum (PA1) and manganese  
946 (PMn). Where values are not reported, the dissolved (D) concentration exceeded the total  
947 dissolvable (TD) concentration, but within the standard deviation of the measurement.  $P = TD -$   
948 D.

949 **Supplemental Fig. 2.** Dissolved Al (DAI) profiles versus potential density from the PANDORA  
950 cruise. Light blue circles show measured DAI concentrations. Orange line represents average  
951 inflow DAI profile, while grey shading represents the range of inflow concentrations. Green box  
952 represents the density interval over which budget of the thermocline waters is calculated. (a–c)  
953 waters that are located south of the Solomon Sea; (d–f) profiles found along the NGCU; (g–i)  
954 profiles that are at the exit straits of the Solomon Sea; (j–l) located outside the Solomon Sea.

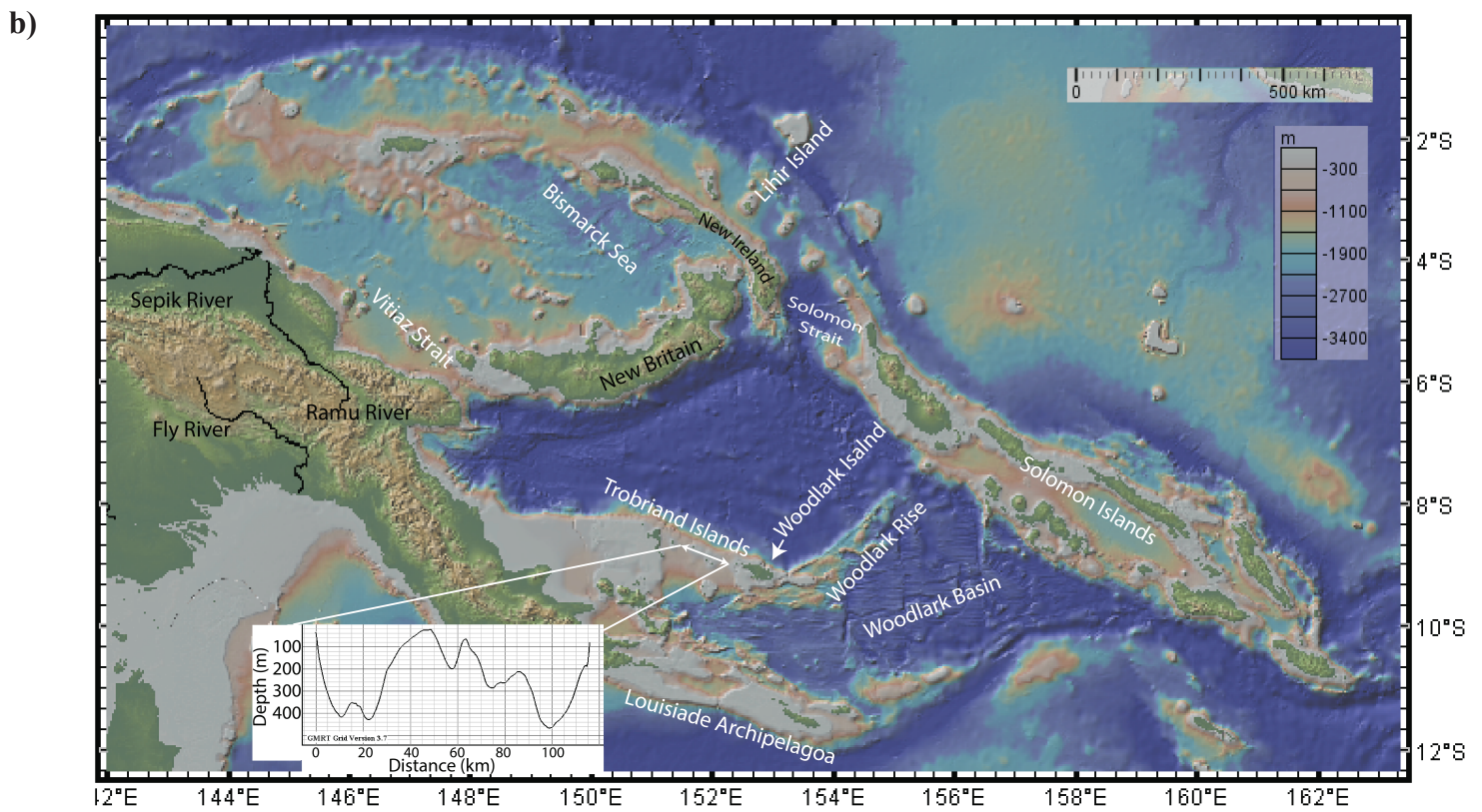
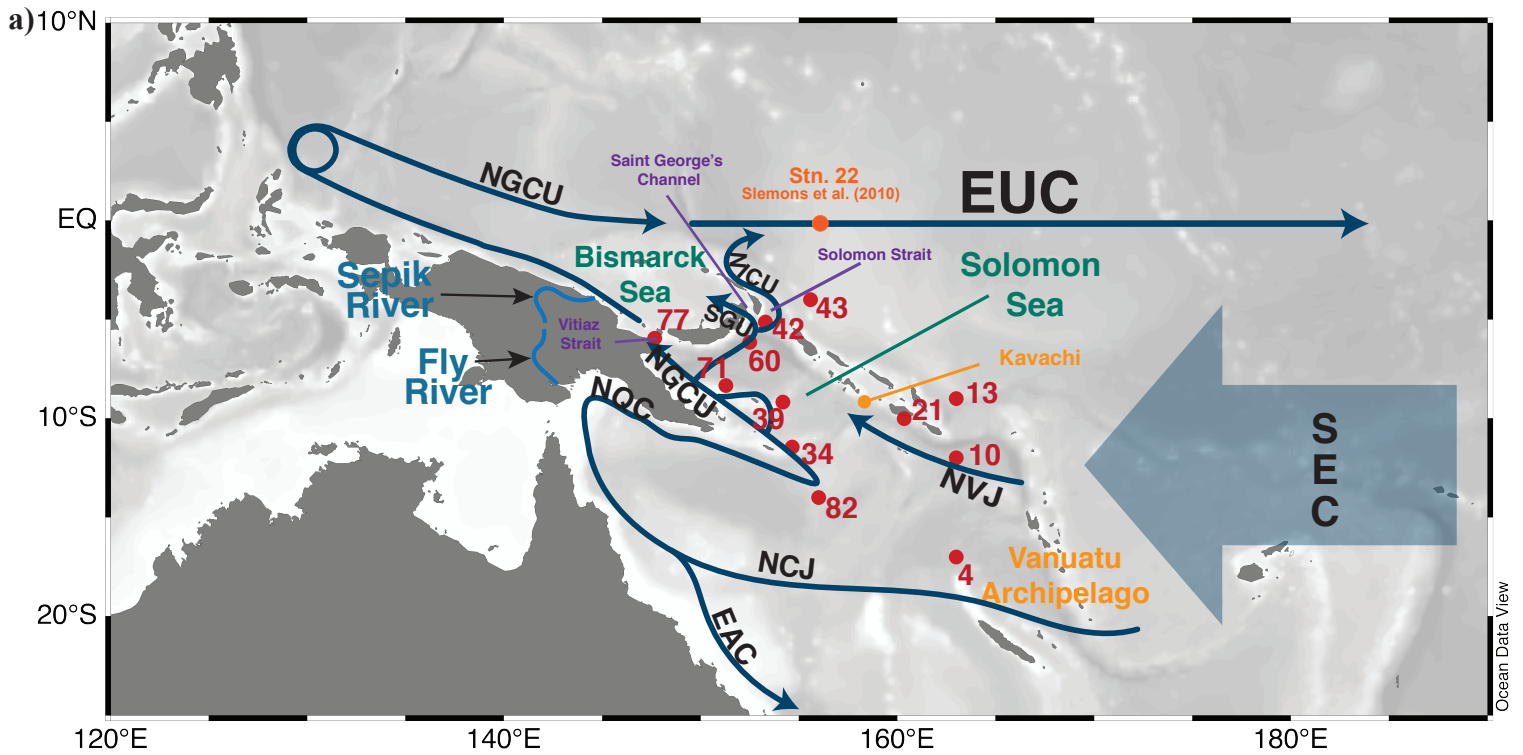
955 **Supplemental Fig. 3.** Total Dissolvable Al (TDAI) profiles versus potential density from the  
956 PANDORA cruise. Dark blue circles show measured TDAI concentrations. Orange line  
957 represents average inflow TDAI profile, while grey shading represents the range of inflow  
958 concentrations. Green box represents the density interval over which budget of the thermocline  
959 waters is calculated. (a–c) waters that are located south of the Solomon Sea; (d–f) profiles found  
960 along the NGCU; (g–i) profiles that are at the exit straits of the Solomon Sea; (j–l) located  
961 outside the Solomon Sea.

962 **Supplemental Fig. 4.** Dissolved Mn (DMn) profiles versus potential density from the  
963 PANDORA cruise. Pink diamonds show measured DMn concentrations. Orange line represents  
964 average inflow DMn profile, while grey shading represents the range of inflow concentrations.  
965 Green box represents the density interval over which budget of the thermocline waters is  
966 calculated. (a–c) waters that are located south of the Solomon Sea; (d–f) profiles found along the  
967 NGCU; (g–i) profiles that are at the exit straits of the Solomon Sea; (j–l) located outside the  
968 Solomon Sea.

969 **Supplemental Fig. 5.** Total Dissolvable Mn (TDMn) profiles versus depth from the PANDORA  
970 cruise. Red diamonds show measured TDMn concentrations. Orange line represents average  
971 inflowing TDMn profile, while grey shading represents the range of inflow concentrations.  
972 Green box represents the density interval over which budget of the thermocline waters is

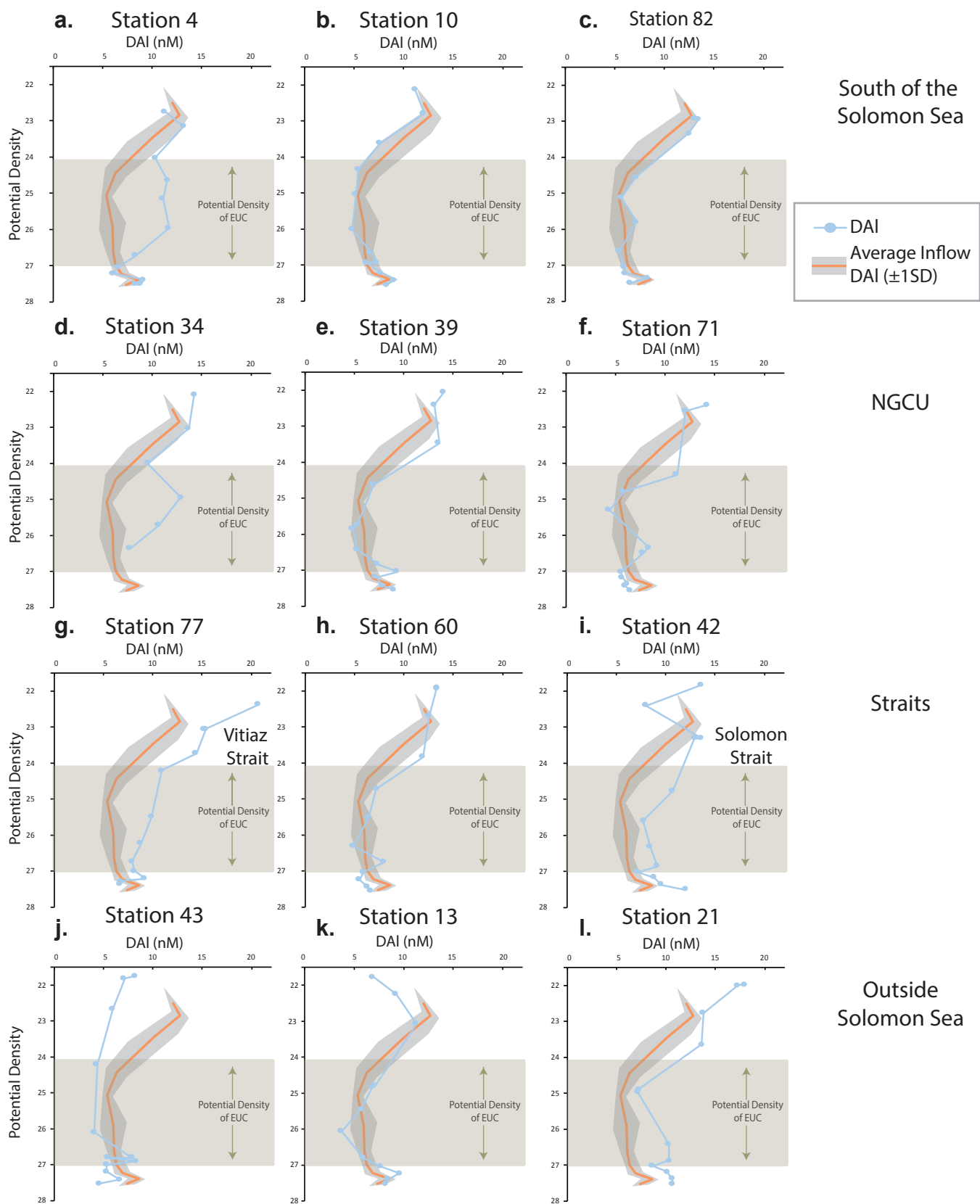
973 calculated. (a–c) waters that are located south of the Solomon Sea; (d–f) profiles found along the  
974 NGCU; (g–i) profiles that are at the exit straits of the Solomon Sea; (j–l) located outside the  
975 Solomon Sea.



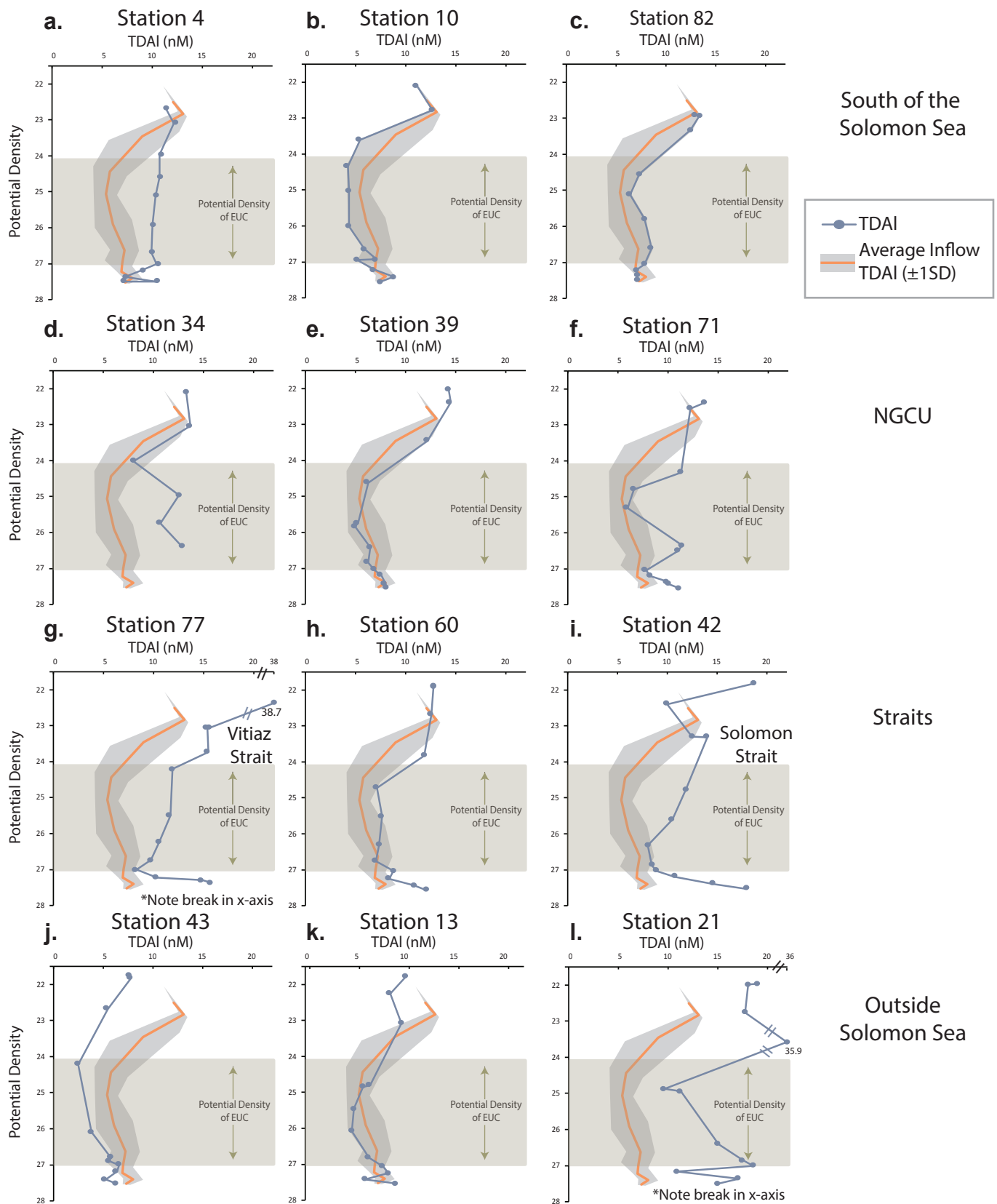


**Fig. 1.** a) Currents [dark blue; after Germaineaud et al. (2016)], rivers (blue text), straits (purple text), and potential point sources (yellow text) to the Solomon Sea. These currents are: Equatorial Undercurrent (EUC); South Equatorial Current (SEC); New Guinea Coastal Undercurrent (NGCU); New Ireland Coastal Undercurrent (NICU); Saint George's Undercurrent (SGU); North Queensland Current (NQC); New Caledonia Jet (NCJ); North Vanuatu Jet (NVJ); East Australian Current (EAC). Red dots and numbers represent stations sampled for Al and Mn.

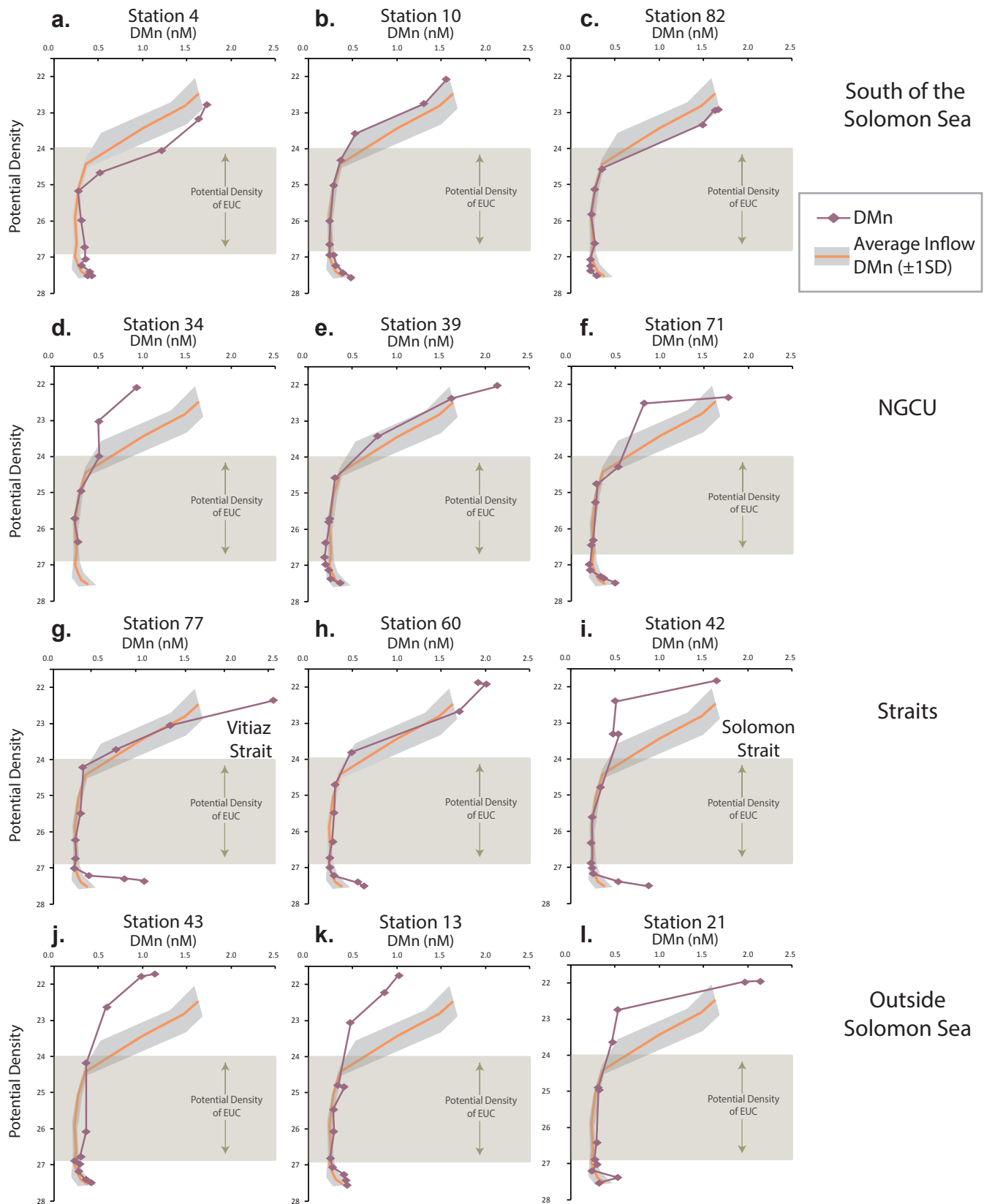
b) Bathymetry of the Woodlark Basin and Trobriand Islands



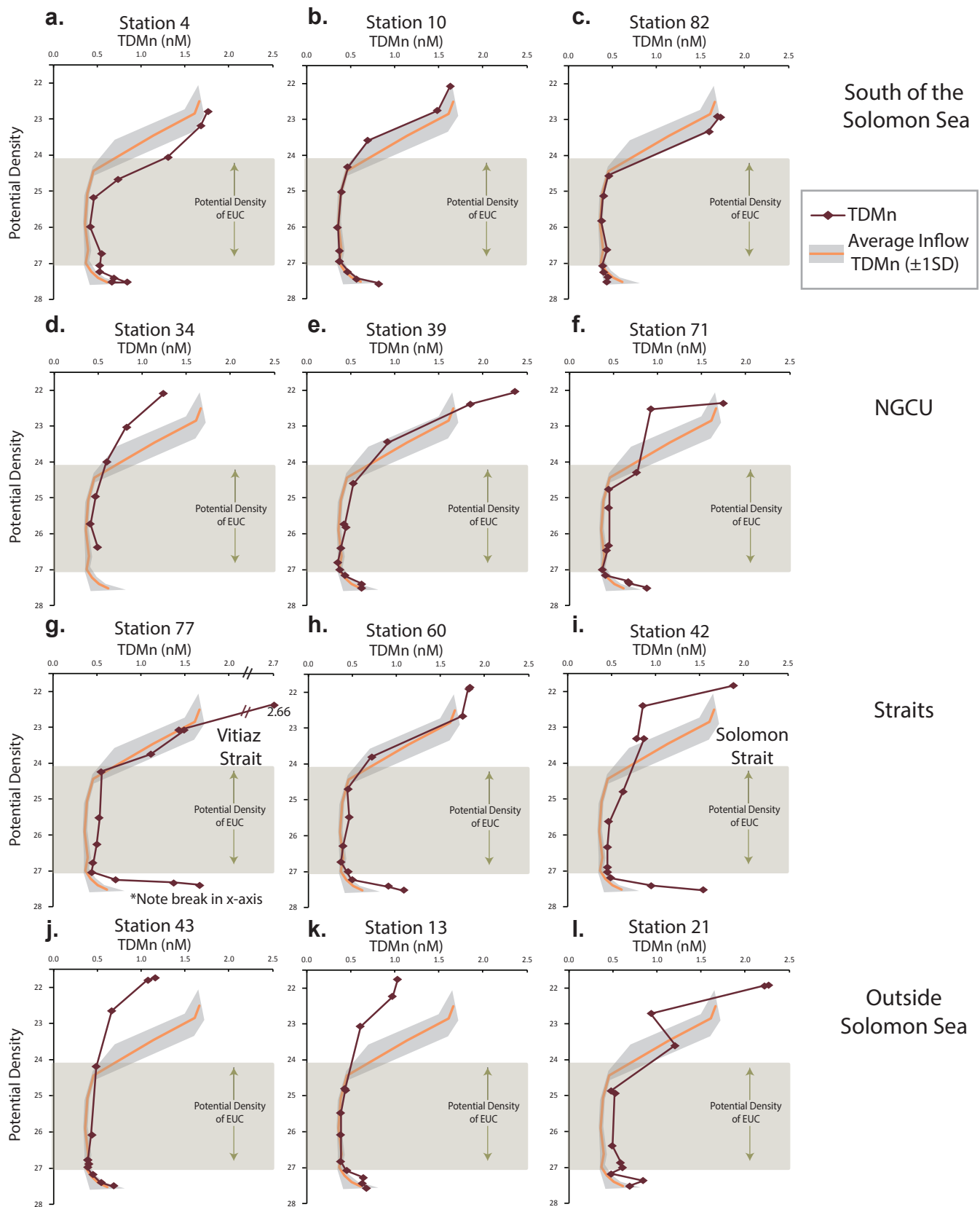
**Fig. 2.** Dissolved Al (DAI) profiles versus potential density from the Pandora cruise. Light blue circles show measured DAI concentrations. Orange line represents average inflow DAI profile, while grey shading represents the range of inflow concentrations. Green box represents the density interval over which budget of the thermocline waters is calculated. (a–c) waters that are located south of the Solomon Sea; (d–f) profiles found along the NGCU; (g–i) profiles that are at the exit straits of the Solomon Sea; (j–l) located outside the Solomon Sea.



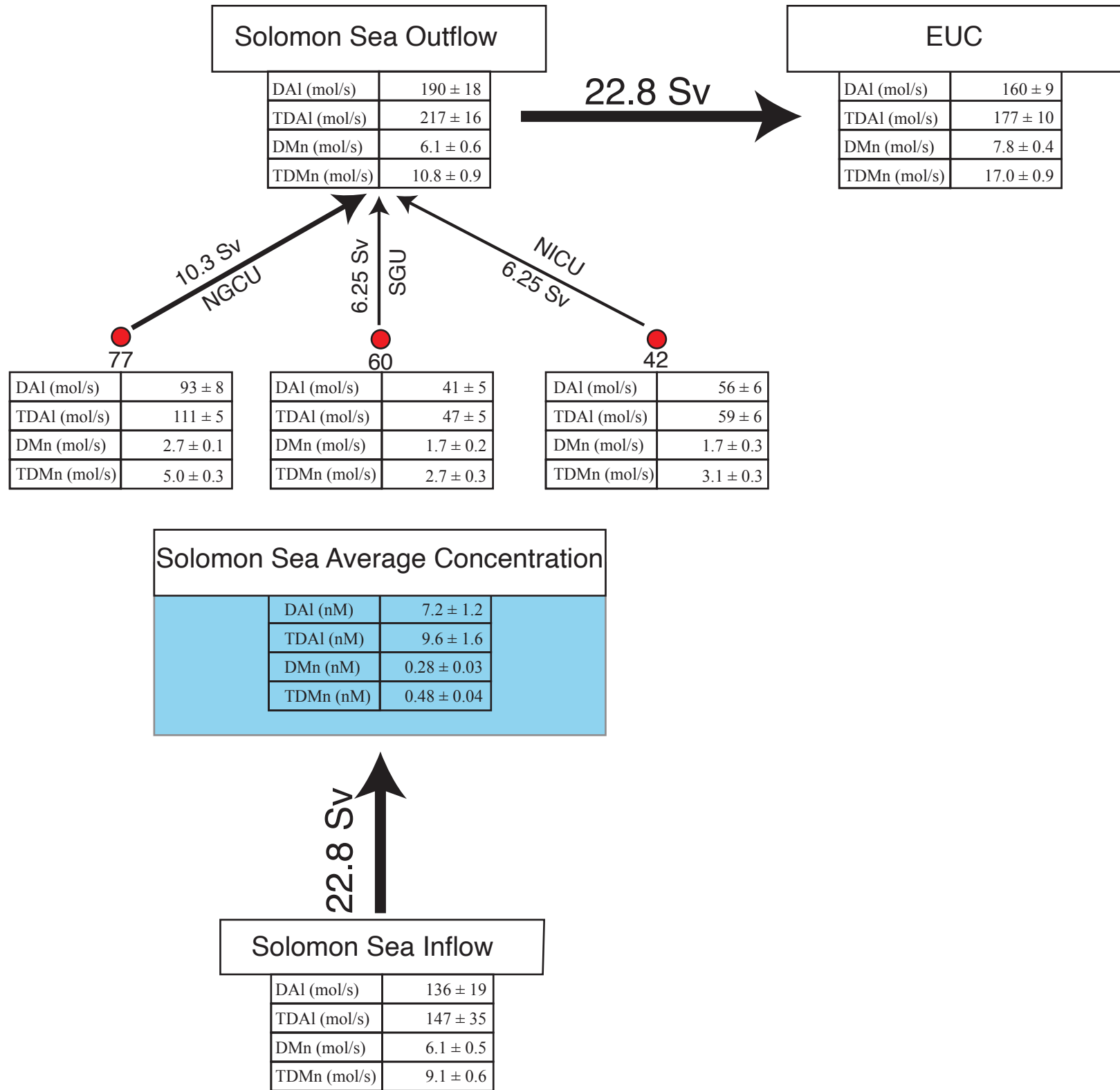
**Fig. 3.** Total Dissolvable Al (TDAI) profiles versus potential density from the PANDORA cruise. Dark blue circles show measured TDAI concentrations. Orange line represents average inflow TDAI profile, while grey shading represents the range of inflow concentrations. Green box represents the density interval over which budget of the thermocline waters is calculated. (a–c) waters that are located south of the Solomon Sea; (d–f) profiles found along the NGCU; (g–i) profiles that are at the exit straits of the Solomon Sea; (j–l) located outside the Solomon Sea.



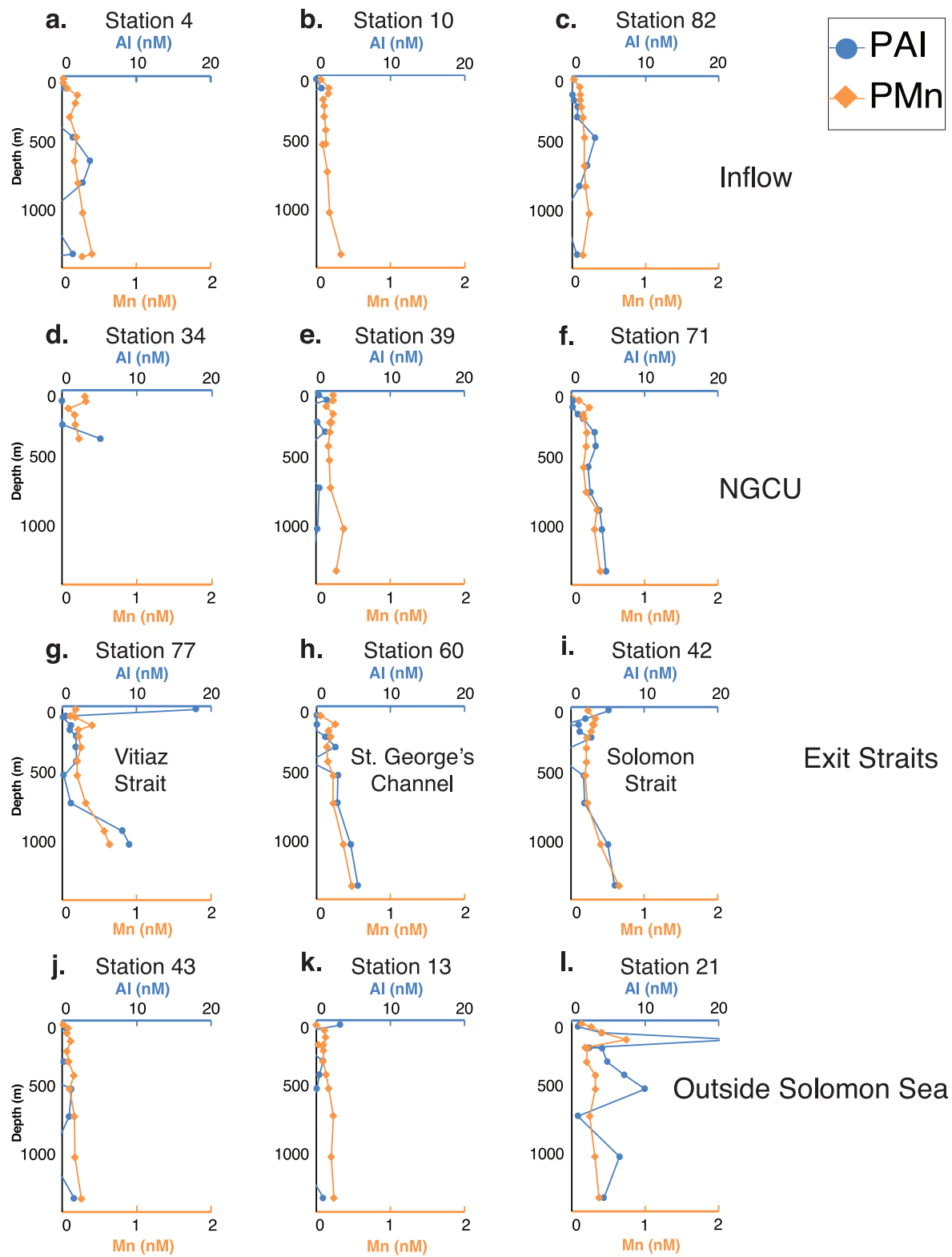
**Fig. 4.** Dissolved Mn (DMn) profiles versus potential density from the PANDORA cruise. Pink diamonds show measured DMn concentrations. Orange line represents average inflow DMn profile, while grey shading represents the range of inflow concentrations. Green box represents the density interval over which budget of the thermocline waters is calculated. (a–c) waters that are located south of the Solomon Sea; (d–f) profiles found along the NGCU; (g–i) profiles that are at the exit straits of the Solomon Sea; (j–l) located outside the Solomon Sea.



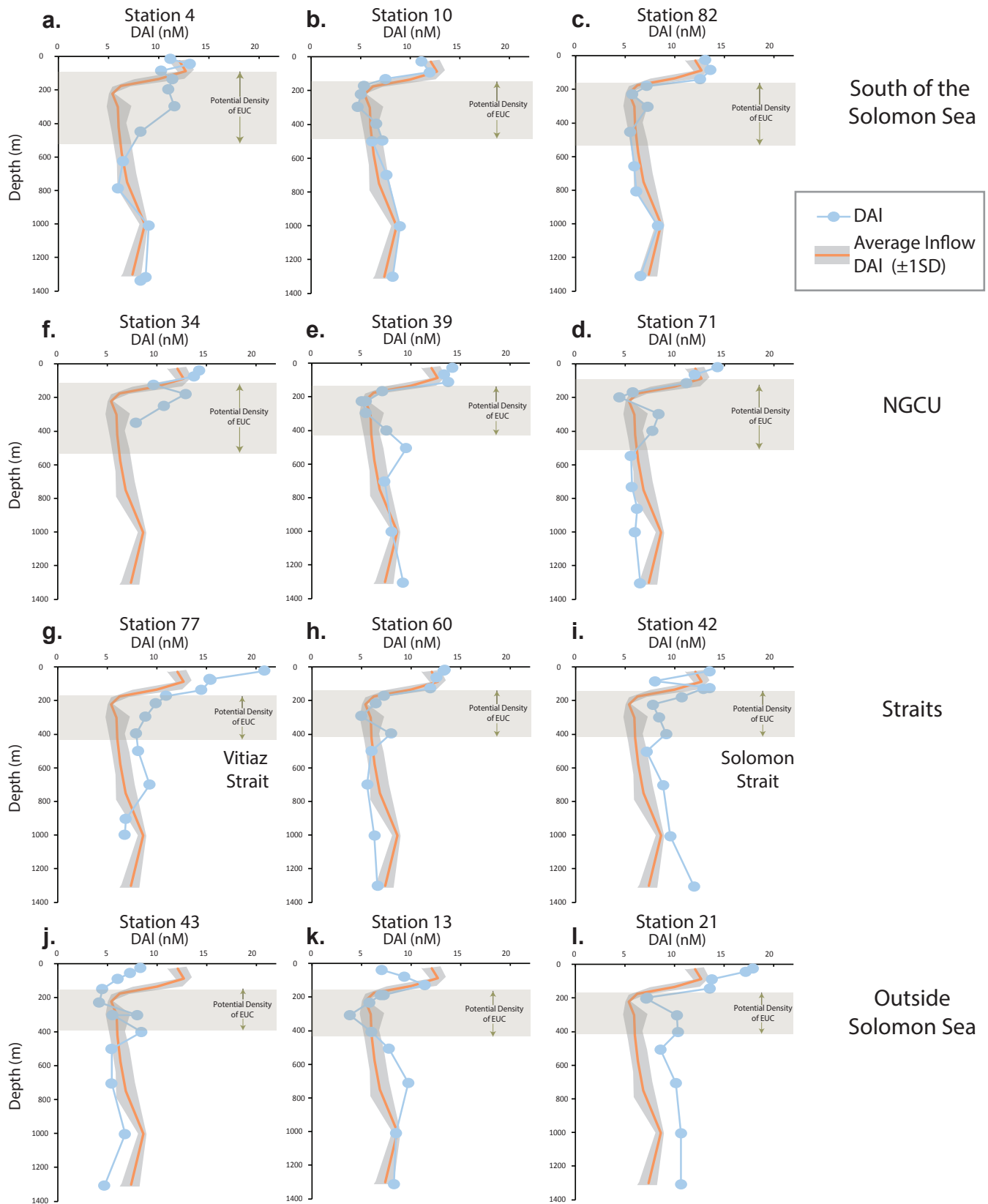
**Fig. 5.** Total Dissolvable Mn (TDMn) profiles versus potential density from the PANDORA cruise. Red diamonds show measured TDMn concentrations. Orange line represents average inflow TDMn profile, while grey shading represents the range of inflow concentrations. Green box represents the density interval over which budget of the thermocline waters is calculated. (a–c) waters that are located south of the Solomon Sea; (d–f) profiles found along the NGCU; (g–i) profiles that are at the exit straits of the Solomon Sea; (j–l) located outside the Solomon Sea.



**Fig. 6.** Budget for 24-26.9  $\sigma_\theta$ , showing the flux of DAI, TDAI, DMn, TDMn at the inflow, the outflow via currents (NGCU, NICU, and SGU), and the flux out of the EUC at 156°E, as well as the average concentration of the Solomon Sea, calculated from stations most representative of the Solomon Sea. Red dots represent stations used to calculate concentrations at each exit strait over the potential density range of the EUC.

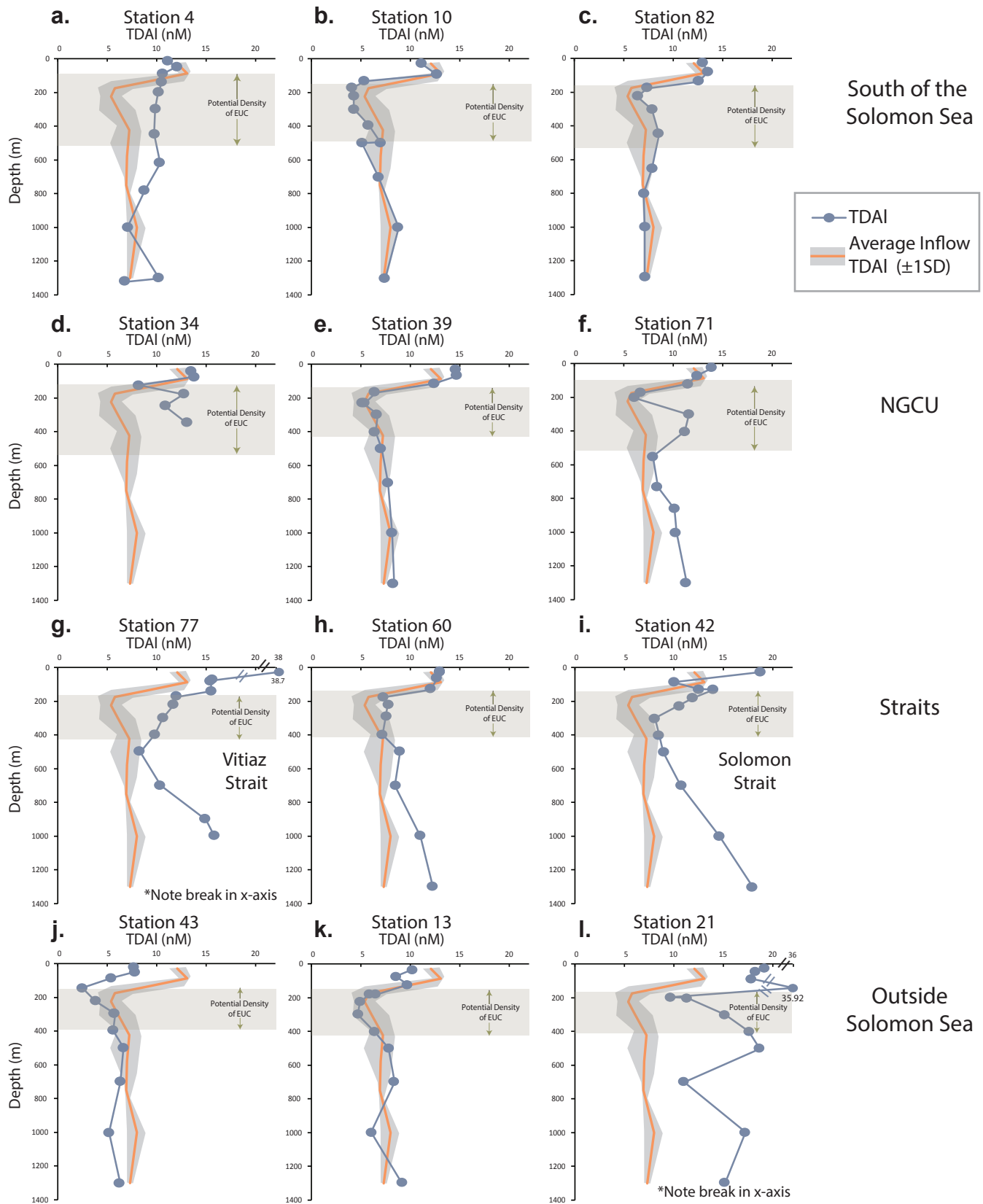


**Supplemental Fig. 1.** Implied labile particle concentrations of aluminum (PAI) and manganese (PMn). Where values are not reported, the dissolved (D) concentration exceeded the total dissolvable (TD) concentration, but within the standard deviation of the measurement.  $P = TD - D$ .

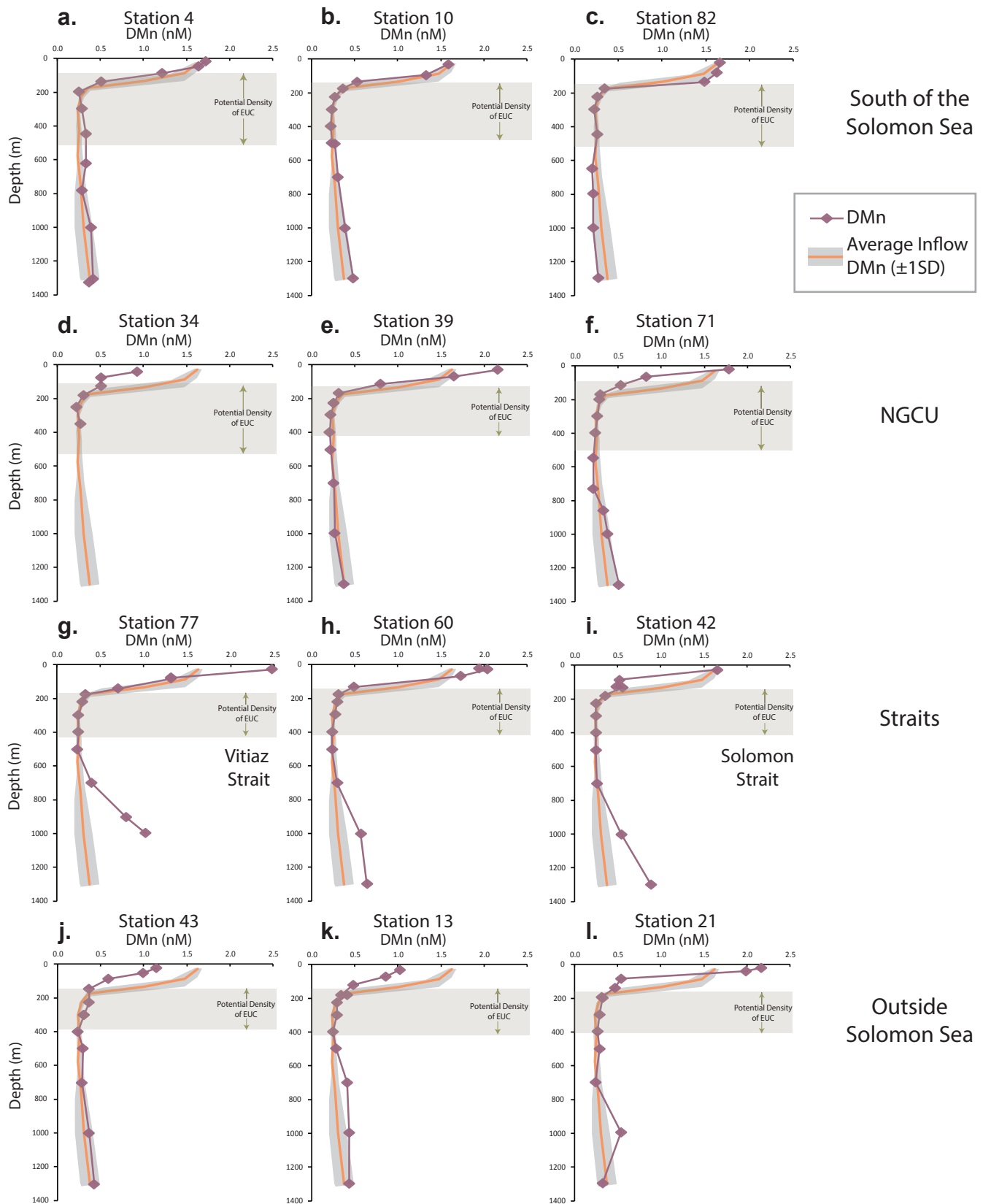


**Supplemental Fig. 2.** Dissolved Al (DAI) profiles versus depth from the PANDORA cruise. Light blue circles show measured DAI concentrations. Orange line represents average inflow DAI profile, while grey shading represents the range of inflow concentrations. Green box represents the density interval over which budget of the thermocline waters is calculated. (a–c) waters that are located south of the Solomon Sea; (d–f) profiles found along the NGCU; (g–i) profiles that are at the exit straits of the Solomon Sea; (j–l) located outside the Solomon Sea.

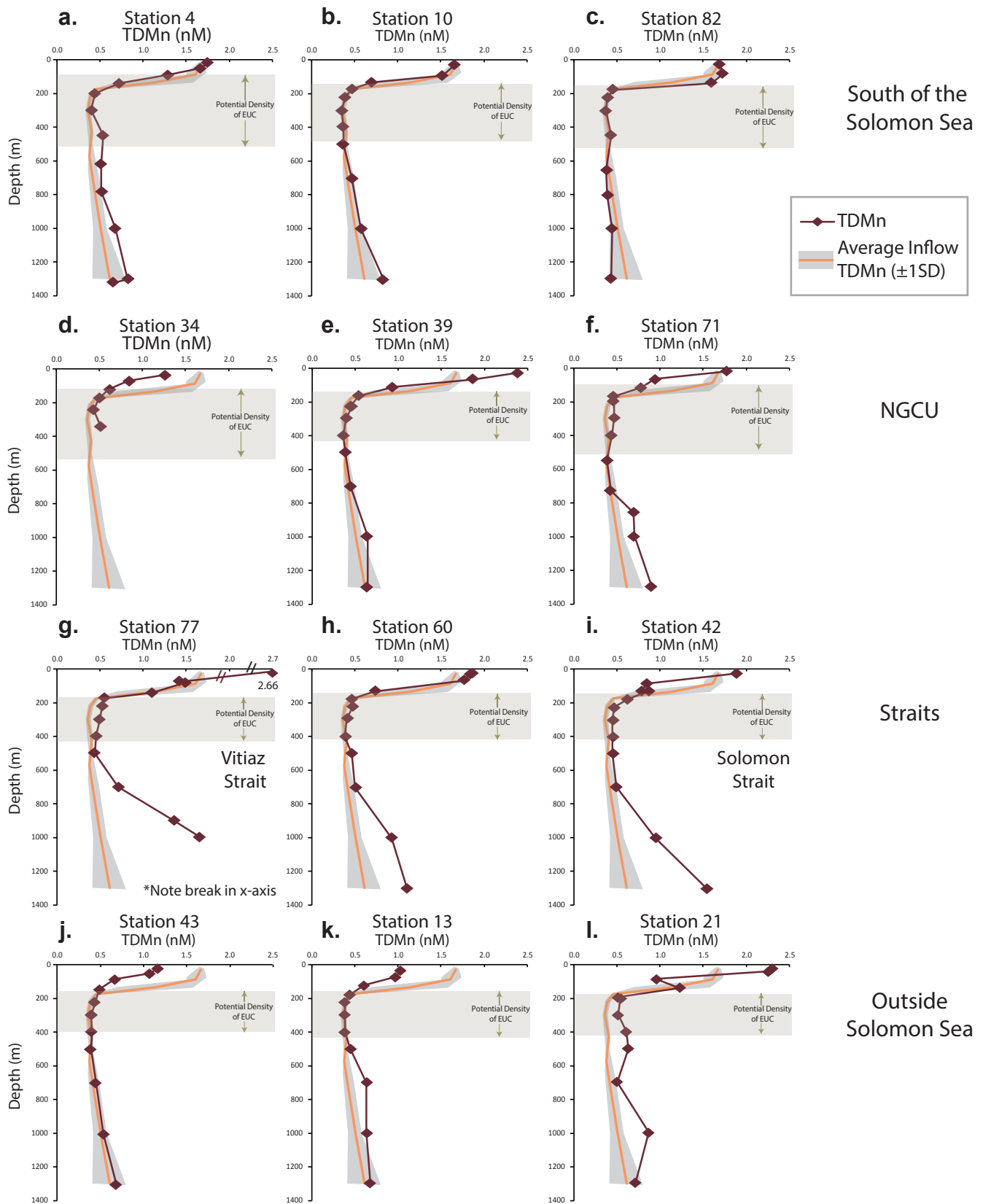




**Supplemental Fig. 3.** Total Dissolvable Al (TDAI) profiles versus depth from the PANDORA cruise. Blue circles show measured TDAI concentrations. Orange line represents average inflow TDAI profile, while grey shading represents the range of inflow concentrations. Green box represents the density interval over which budget of the thermocline waters is calculated. (a–c) waters that are located south of the Solomon Sea; (d–f) profiles found along the NGCU; (g–i) profiles that are at the exit straits of the Solomon Sea; (j–l) located outside the Solomon Sea.



**Supplemental Fig. 4.** Dissolved Mn (DMn) profiles versus potential density from the PANDORA cruise. Pink diamonds show measured DMn concentrations. Orange line represents average inflow DMn profile, while grey shading represents the range of inflow concentrations. Green box represents the density interval over which budget of the thermocline waters is calculated. (a–c) waters that are located south of the Solomon Sea; (d–f) profiles found along the NGCU; (g–i) profiles that are at the exit straits of the Solomon Sea; (j–l) located outside the Solomon Sea.



**Supplemental Fig. 5.** Total Dissolvable Mn (TDMn) profiles versus depth from the PANDORA cruise. Red diamonds show measured TDMn concentrations. Orange line represents average inflow TDMn profile, while grey shading represents the range of inflow concentrations. Green box represents the density interval over which budget of the thermocline waters is calculated. (a–c) waters that are located south of the Solomon Sea; (d–f) profiles found along the NGCU; (g–i) profiles that are at the exit straits of the Solomon Sea; (j–l) located outside the Solomon Sea.

**Table S1:** Potential density thresholds and corresponding depths used to calculate average concentrations over each depth range.

Station	Surface (m)	24 $\sigma_\theta$ (m)	26.9 $\sigma_\theta$ (m)	Deep ( $\sim 27.5\sigma_\theta$ ) (m)
4	18	87	525	1321
10	31	150	490	1303
13	34	152	430	1299
21	26	170	415	1302
34	47	130	*	
39	26	137	430	1299
42	25	150	420	1301
43	25	152	405	1302
60	23	145	420	1300
71	23	105	515	1300
77	25	173	435	999
82	24	158	530	1298

\*Profile collected only to 353 m (26.4  $\sigma_\theta$ )

**Table S2:** PANDORA Al and Mn dataset. Error reported is 1 standard deviation of the measurement

Latitude	Longitude	STATION	Depth (m)	DAI (nM)	DAI_1SD_(nM)	TDAI_nM	TDAI_1SD_nM	DMn (nM)	DMn_1SD_(nM)	TDMn (nM)	TDMn_1SD_(nM)
-17.00	163.00	4	18	11.2	0.4	11.2	0.4	1.72	0.07	1.74	0.07
-17.00	163.00	4	50	13.1	0.4	12.1	0.4	1.63	0.07	1.66	0.07
-17.00	163.00	4	88	10.3	0.4	10.7	0.4	1.21	0.05	1.28	0.05
-17.00	163.00	4	139	11.5	0.4	10.6	0.4	0.51	0.02	0.72	0.03
-17.00	163.00	4	198	11.0	0.4	10.2	0.4	0.26	0.00	0.44	0.02
-17.00	163.00	4	298	11.6	0.4	9.9	0.4	0.29	0.00	0.40	0.02
-17.00	163.00	4	448	8.2	0.4	9.8	0.4	0.33	0.00	0.53	0.02
-17.00	163.00	4	619	6.5	0.4	10.3	0.4	0.34	0.00	0.51	0.02
-17.00	163.00	4	780	6.0	0.4	8.8	0.4	0.29	0.00	0.51	0.02
-17.00	163.00	4	1000	9.0	0.4	7.1	0.4	0.39	0.02	0.67	0.03
-17.00	163.00	4	1300	8.7	0.4	10.3	0.4	0.42	0.02	0.82	0.03
-17.00	163.00	4	1321	8.2	0.4	6.9	0.4	0.37	0.00	0.65	0.03
-12.00	163.00	10	31	11.1	0.4	11.1	0.4	1.59	0.06	1.65	0.07

-12.00	163.00	10	95	11.9	0.4	12.7	0.4	1.33	0.05	1.50	0.06
-12.00	163.00	10	135	7.6	0.4	5.4	0.4	0.53	0.02	0.70	0.03
-12.00	163.00	10	175	5.4	0.4	4.2	0.4	0.37	0.02	0.47	0.02
-12.00	163.00	10	224	5.1	0.4	4.3	0.4	0.28	0.00	0.39	0.00
-12.00	163.00	10	301	4.7	0.4	4.3	0.4	0.24	0.00	0.35	0.00
-12.00	163.00	10	399	6.6	0.4	5.9	0.4	0.24	0.00	0.37	0.00
-12.00	163.00	10	500	7.2	0.4	7.0	0.4	0.24	0.00	0.37	0.01
-12.00	163.00	10	501	6.2	0.4	5.1	0.4	0.28	0.00	0.37	0.01
-12.00	163.00	10	700	7.6	0.4	6.8	0.4	0.32	0.00	0.47	0.02
-12.00	163.00	10	1002	8.9	0.4	8.8	0.4	0.39	0.00	0.57	0.02
-12.00	163.00	10	1303	8.3	0.4	7.5	0.4	0.49	0.02	0.83	0.03
-9.00	163.00	13	34	6.9	0.5	10.2	0.5	1.02	0.04	1.02	0.04
-9.00	163.00	13	74	9.3	0.5	8.6	0.5	0.85	0.03	0.96	0.04
-9.00	163.00	13	125	11.3	0.5	9.7	0.5	0.47	0.02	0.60	0.02
-9.00	163.00	13	179	7.1	0.5	6.5	0.5	0.33	0.05	0.43	0.02
-9.00	163.00	13	181	6.9	0.5	5.9	0.5	0.40	0.05	0.44	0.02
-9.00	163.00	13	225	5.8	0.5	4.9	0.5	0.28	0.05	0.38	0.05
-9.00	163.00	13	298	3.8	0.5	4.7	0.5	0.29	0.05	0.38	0.05
-9.00	163.00	13	400	6.0	0.5	6.4	0.5	0.25	0.05	0.38	0.05
-9.00	163.00	13	501	7.7	0.5	7.8	0.5	0.28	0.05	0.44	0.02
-9.00	163.00	13	700	9.6	0.5	8.4	0.5	0.40	0.05	0.63	0.03
-9.00	163.00	13	1000	8.5	0.5	6.1	0.5	0.42	0.02	0.63	0.03
-9.00	163.00	13	1299	8.2	0.5	9.2	0.5	0.43	0.02	0.67	0.03
-10.01	160.36	21	26	17.9	0.4	19.1	0.4	2.15	0.09	2.28	0.09
-10.01	160.36	21	45	17.2	0.4	18.1	0.4	1.97	0.08	2.24	0.09
-10.01	160.36	21	89	13.8	0.4	17.8	0.4	0.54	0.02	0.95	0.04
-10.01	160.36	21	140	13.6	0.4	35.9	0.4	0.48	0.02	1.22	0.05
-10.01	160.36	21	198	7.3	0.4	9.6	0.5	0.32	0.05	0.50	0.02
-10.01	160.36	21	202	7.2	0.4	11.3	0.4	0.33	0.05	0.54	0.02
-10.01	160.36	21	303	10.3	0.4	15.1	0.5	0.30	0.02	0.51	0.02
-10.01	160.36	21	401	10.3	0.4	17.5	0.4	0.28	0.05	0.60	0.02
-10.01	160.36	21	504	8.6	0.4	18.6	0.6	0.30	0.02	0.62	0.02
-10.01	160.36	21	700	10.1	0.4	10.9	0.5	0.25	0.05	0.49	0.02
-10.01	160.36	21	1002	10.7	0.4	17.1	0.5	0.55	0.02	0.86	0.03
-10.01	160.36	21	1302	10.7	0.4	15.1	0.5	0.34	0.02	0.71	0.03
-11.45	154.67	34	47	14.3	0.3	13.4	0.3	0.93	0.18	1.24	0.05
-11.45	154.67	34	79	13.7	0.3	13.8	0.3	0.51	0.02	0.83	0.03
-11.45	154.67	34	129	9.6	0.3	8.2	0.3	0.51	0.02	0.60	0.02
-11.45	154.67	34	181	12.9	0.3	12.7	0.3	0.31	0.02	0.48	0.02
-11.45	154.67	34	249	10.7	0.3	10.8	0.3	0.24	0.02	0.42	0.02

-11.45	154.67	34	353	7.8	0.3	13.0	0.3	0.28	0.02	0.50	0.02
-9.17	154.19	39	26	14.2	0.3	14.6	0.3	2.16	0.09	2.38	0.10
-9.17	154.19	39	63	13.3	0.3	14.7	0.3	1.64	0.07	1.87	0.07
-9.17	154.19	39	111	13.7	0.3	12.4	0.3	0.80	0.03	0.93	0.04
-9.19	154.17	39	163	7.1	0.3	6.4	0.3	0.31	0.02	0.54	0.02
-9.19	154.17	39	221	5.4	0.3	5.4	0.3	0.25	0.02	0.44	0.02
-9.19	154.17	39	227	5.0	0.3	5.1	0.3	0.25	0.02	0.46	0.02
-9.19	154.17	39	295	5.5	0.3	6.7	0.3	0.21	0.02	0.40	0.02
-9.19	154.17	39	397	7.6	0.3	6.4	0.3	0.20	0.02	0.36	0.02
-9.19	154.17	39	500	9.5	0.3	7.1	0.3	0.21	0.02	0.39	0.02
-9.19	154.17	39	700	7.3	0.3	7.7	0.3	0.25	0.02	0.44	0.02
-9.19	154.17	39	998	8.0	0.3	8.2	0.3	0.26	0.02	0.64	0.03
-9.19	154.17	39	1299	9.2	0.3	8.3	0.3	0.37	0.02	0.64	0.03
-5.14	153.30	42	25	13.5	0.4	18.7	0.4	1.64	0.07	1.88	0.08
-5.14	153.30	42	83	8.0	0.4	9.9	0.4	0.51	0.02	0.84	0.03
-5.14	153.30	42	129	13.5	0.3	12.4	0.4	0.48	0.02	0.78	0.03
-5.14	153.30	42	130	12.9	0.4	13.9	0.4	0.55	0.02	0.86	0.03
-5.15	153.29	42	181	10.6	0.4	11.9	0.4	0.35	0.02	0.62	0.02
-5.15	153.29	42	227	7.7	0.4	10.5	0.4	0.24	0.02	0.46	0.02
-5.15	153.29	42	297	8.4	0.4	8.0	0.4	0.24	0.02	0.45	0.02
-5.12	153.33	42	401	9.1	0.3	8.4	0.4	0.24	0.02	0.45	0.02
-5.12	153.33	42	501	7.1	0.3	8.9	0.4	0.25	0.02	0.45	0.02
-5.12	153.33	42	700	8.8	0.3	10.7	0.4	0.26	0.02	0.49	0.02
-5.12	153.33	42	1000	9.5	0.3	14.6	0.4	0.54	0.02	0.94	0.04
-5.12	153.33	42	1301	11.9	0.3	17.9	0.4	0.88	0.04	1.53	0.06
-4.00	155.59	43	25	8.3	0.4	7.7	0.5	1.15	0.05	1.16	0.05
-4.00	155.59	43	56	7.2	0.4	7.9	0.5	0.99	0.04	1.07	0.04
-4.00	155.59	43	91	6.0	0.4	5.5	0.5	0.60	0.02	0.66	0.03
-4.00	155.59	43	160	4.5	0.5	2.5	0.3	0.37	0.01	0.49	0.02
-4.00	155.59	43	224	4.2	0.4	3.9	0.5	0.37	0.08	0.44	0.02
-4.00	155.59	43	300	8.0	0.4	5.8	0.5	0.31	0.08	0.39	0.02
-4.00	155.59	43	300	5.6	0.4	5.8	0.5	0.30	0.08	0.39	0.02
-4.00	155.59	43	401	8.4	0.5	5.6	0.3	0.24	0.01	0.40	0.02
-4.00	155.59	43	500	5.4	0.5	6.7	0.3	0.29	0.01	0.39	0.02
-4.00	155.59	43	701	5.5	0.5	6.4	0.3	0.28	0.01	0.45	0.02
-4.00	155.59	43	1002	6.7	0.5	5.3	0.3	0.37	0.01	0.54	0.02
-4.00	155.59	43	1302	4.7	0.5	6.4	0.3	0.42	0.02	0.68	0.03
-6.17	152.50	60	23	13.3	0.3	12.9	0.3	1.92	0.08	1.85	0.07
-6.17	152.50	60	29	13.3	0.3	12.9	0.3	2.01	0.08	1.83	0.07
-6.17	152.50	60	65	12.5	0.3	12.6	0.3	1.71	0.07	1.76	0.07

-6.17	152.50	60	127	11.9	0.3	12.0	0.3	0.48	0.02	0.73	0.03
-6.17	152.50	60	176	7.2	0.3	7.2	0.3	0.30	0.01	0.46	0.02
-6.17	152.50	60	220	6.4	0.3	7.7	0.3	0.29	0.01	0.48	0.02
-6.17	152.50	60	293	4.9	0.3	7.4	0.3	0.27	0.01	0.41	0.02
-6.17	152.50	60	401	8.0	0.3	7.1	0.3	0.23	0.01	0.38	0.02
-6.17	152.50	60	499	5.9	0.3	8.8	0.3	0.23	0.01	0.46	0.02
-6.17	152.50	60	699	5.5	0.3	8.4	0.3	0.28	0.01	0.50	0.02
-6.17	152.50	60	1000	6.3	0.3	10.9	0.3	0.56	0.02	0.92	0.04
-6.17	152.50	60	1300	6.6	0.3	12.2	0.3	0.63	0.03	1.10	0.04
-8.34	151.29	71	23	14.3	0.6	13.9	0.6	1.79	0.07	1.77	0.07
-8.34	151.29	71	69	12.0	0.6	12.3	0.6	0.84	0.03	0.94	0.04
-8.34	151.29	71	118	11.2	0.6	11.4	0.6	0.54	0.02	0.78	0.03
-8.34	151.29	71	168	5.8	0.6	6.7	0.6	0.30	0.01	0.46	0.02
-8.34	151.29	71	201	4.3	0.6	6.0	0.6	0.28	0.01	0.46	0.02
-8.33	151.29	71	299	8.3	0.6	11.5	0.6	0.26	0.01	0.46	0.02
-8.33	151.29	71	400	7.7	0.6	11.1	0.6	0.24	0.01	0.44	0.02
-8.33	151.29	71	551	5.5	0.6	7.9	0.6	0.21	0.01	0.38	0.02
-8.33	151.29	71	730	5.7	0.6	8.3	0.6	0.22	0.01	0.42	0.02
-8.33	151.29	71	860	6.2	0.6	10.0	0.6	0.34	0.01	0.69	0.03
-8.33	151.29	71	1000	6.0	0.6	10.2	0.6	0.38	0.01	0.70	0.03
-8.33	151.29	71	1300	6.5	0.6	11.2	0.6	0.51	0.02	0.90	0.04
-5.95	147.67	77	25	20.7	0.4	38.7	0.4	2.48	0.10	2.66	0.11
-5.95	147.67	77	75	15.3	0.4	15.7	0.4	1.31	0.05	1.42	0.06
-5.95	147.67	77	81	15.4	0.4	15.5	0.4	1.32	0.05	1.49	0.06
-5.95	147.66	77	142	14.4	0.4	15.6	0.4	0.70	0.03	1.10	0.04
-5.95	147.66	77	174	11.0	0.4	12.0	0.4	0.33	0.01	0.54	0.02
-5.95	147.66	77	220	9.9	0.4	11.8	0.4	0.30	0.01	0.52	0.02
-5.95	147.66	77	299	8.9	0.4	10.7	0.4	0.24	0.01	0.49	0.02
-5.95	147.66	77	398	8.0	0.4	9.9	0.4	0.25	0.01	0.45	0.02
-5.95	147.66	77	501	8.2	0.4	8.4	0.4	0.23	0.01	0.43	0.02
-5.95	147.66	77	702	9.3	0.4	10.4	0.4	0.40	0.01	0.71	0.03
-5.95	147.66	77	902	6.9	0.4	15.0	0.4	0.80	0.03	1.36	0.05
-5.95	147.66	77	999	6.8	0.4	15.8	0.4	1.02	0.04	1.65	0.07
-14.00	156.01	82	24	13.0	0.4	13.0	0.4	1.66	0.07	1.68	0.07
-14.00	156.01	82	80	13.5	0.4	13.4	0.4	1.63	0.07	1.72	0.07
-14.00	156.01	82	135	12.5	0.4	12.5	0.4	1.48	0.06	1.59	0.06
-14.00	156.01	82	174	7.1	0.4	7.3	0.4	0.34	0.01	0.45	0.02
-14.00	156.01	82	224	5.6	0.4	6.4	0.4	0.27	0.01	0.39	0.02
-14.00	156.01	82	300	7.2	0.4	7.8	0.4	0.23	0.01	0.37	0.01
-14.00	156.01	82	447	5.4	0.4	8.5	0.4	0.27	0.01	0.43	0.02

-14.00	156.01	82	651	5.9	0.4	7.9	0.4	0.21	0.01	0.38	0.02
-14.00	156.01	82	799	6.1	0.4	7.0	0.4	0.22	0.01	0.39	0.02
-14.00	156.01	82	1001	8.3	0.4	7.1	0.4	0.22	0.01	0.44	0.02
-14.00	156.01	82	1298	6.5	0.4	7.1	0.4	0.28	0.01	0.43	0.02