Physical data report by station

Station n°134

LMD / UMR 8539 / Paris / France
LPO / UMR 6523 / Brest / France
IBENS / INSERM 1024 stations/ CNRS 8197 / Paris / France

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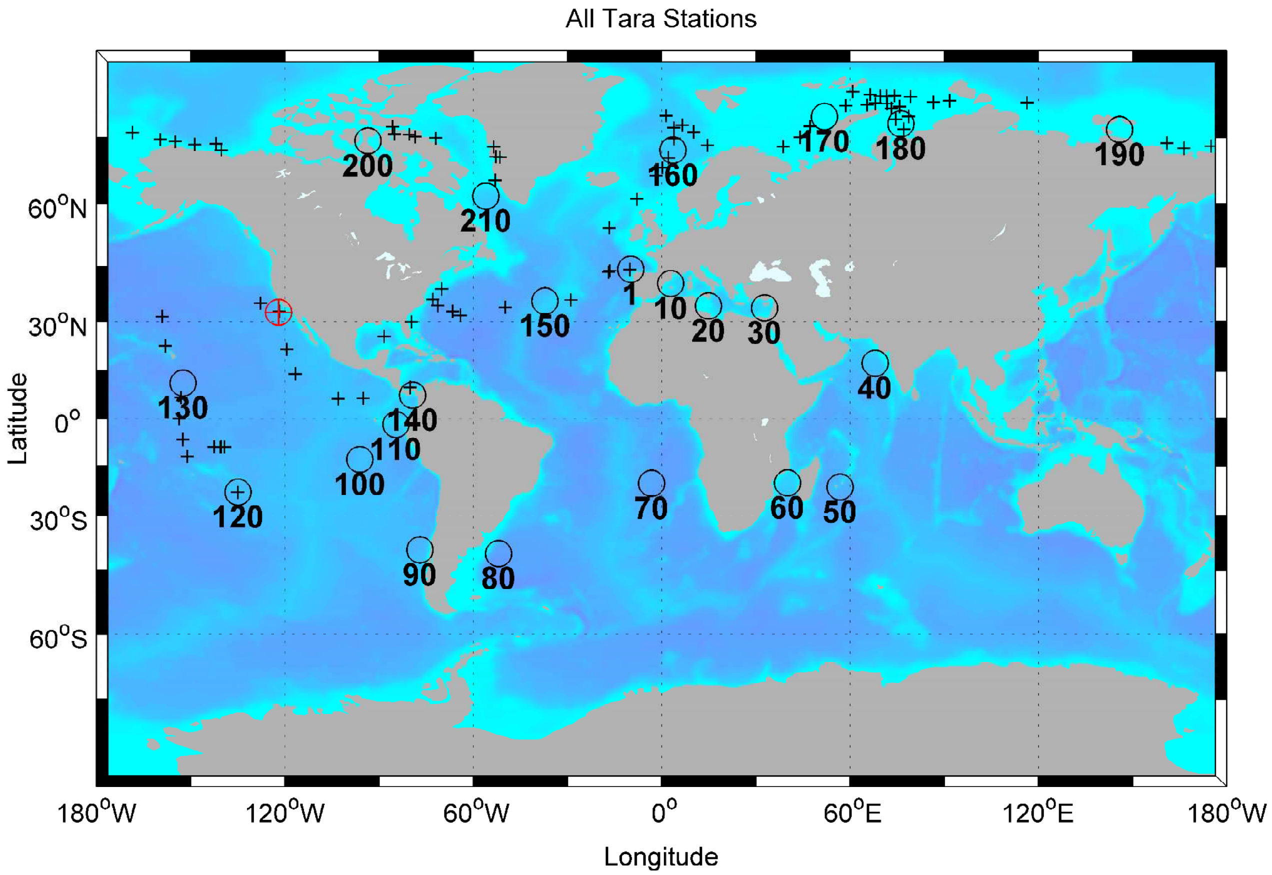

Contents

Station overview

We present here the geographical situation of the station and a quick overview of the physical data available. For more information please see the next sections. About availability in the table below, 1 means "available" and 0 "not available".

Station n°	134
Location	North Pacific Ocean
Date	22/10/2011
Mean Longitude	-121.9884°
Mean Latitude	32.6714°
CTDs profiles	2

Availability:	
UV Satellite fields	1
SST Satellite fields	1
SSS Satellite fields	1
SSH Satellite fields	1
CHL1 Satellite fields	1
Argo floats	1

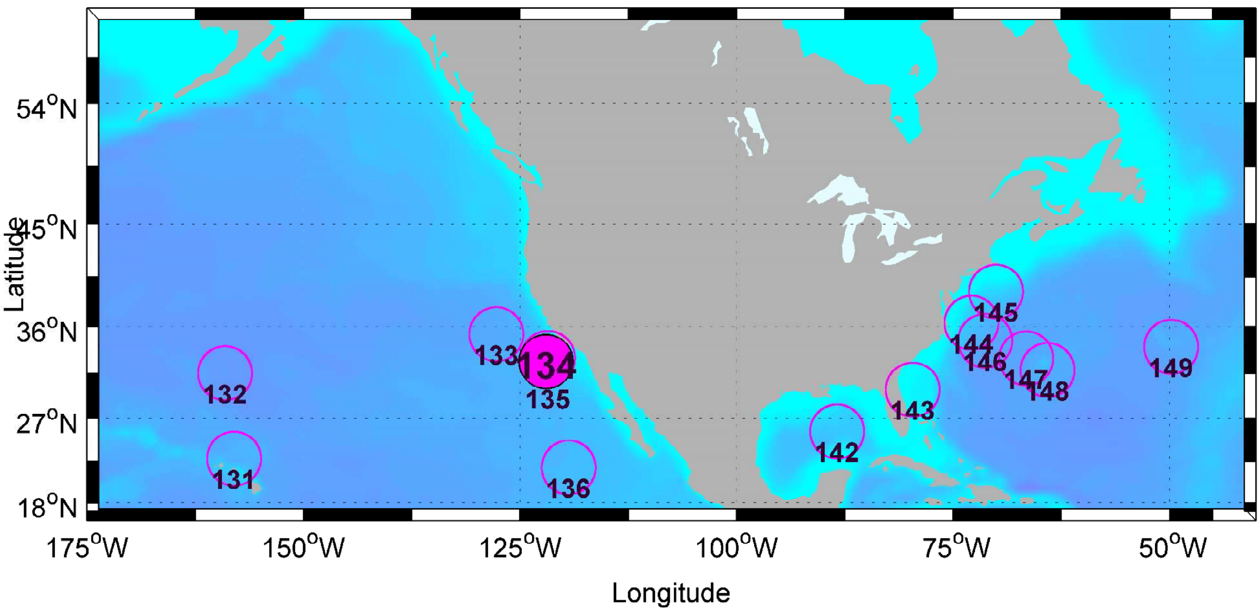

Figure 1: Filled magenta black circle indicate the station of this study.

1 Sea surface temperature, height and chlorophyll

1.1 Introduction

We present here several sea surface properties at the station position using satellite data (SSH $[m]$ in Fig.2 and Fig.3, the SST $[°C]$ in Fig.4 and Fig.5 and the CHL1 $[mg/m^3]$ in Fig.6 and Fig.7). We give definitions and information about these quantities below:

- Sea Surface Height (SSH): Maps of Absolute Dynamic Topography (MADT) from the global 1/4° (approx. $27km$) Daily Delayed Time Archiving Validation and Interpretation of Satellite Data in Oceanography (AVISO) field (Rio and Hernandez, 2004; Capet et al., 2014). The altimeter products were produced by Ssalto/Duacs and distributed by Aviso, with support from Cnes (`http://www.aviso.oceanobs.com/duacs/`).
- Sea Surface Temperature (SST): OSTIA uses satellite data provided by the GHRSST project, together with in-situ observations to determine the sea surface temperature. The analysis is performed using a variant of optimal interpolation (OI) described by Martin et al. (2007). The National Centre for Ocean Forecasting produces the analysis at a resolution of 1/20° (approx. $5km$). OSTIA data is provided in GHRSST netCDF format every day.
- Chlorophyll (CHL1): Weekly 1/10°Chlorophyll maps processed and distributed by ACRI-ST GlobColour service, supported by EU FP7 MyOcean & ESA GlobColour Projects, using ESA ENVISAT MERIS data, NASA MODIS and SeaWiFS data.

Legend In order to relieve figures we describe here their general legend:

- ● indicate the casts of Tara stations identified by their respective numbers.
- ○ are used to locate other Tara's stations around.
- □ refer to CTD profiles. When filled, each colour corresponds to a reference used in profiles plots (see CTD section) to make distinction between them.
- We indicate bathymetry by grey contours, horizontal geostrophic surface velocity field by dark arrows proportional to the current intensity, and SSH field by white contours.
- The ▼ is the nearest coast point (zlevel=0) of each ctd profile from etopo2 database
- When shown, $\bigtriangledown$ represent Argo's data available around the mean longitude and latitude position of CTDs. We defined a box around the mean position with $\Delta X \pm 4°\ lat - lon$ and $\Delta t \pm 15\ julian\ days$. Argo's numbers are only an index.
- Date refers to the day when SST, SSH or Chlorophyll maps are available.

1.2 SSH maps

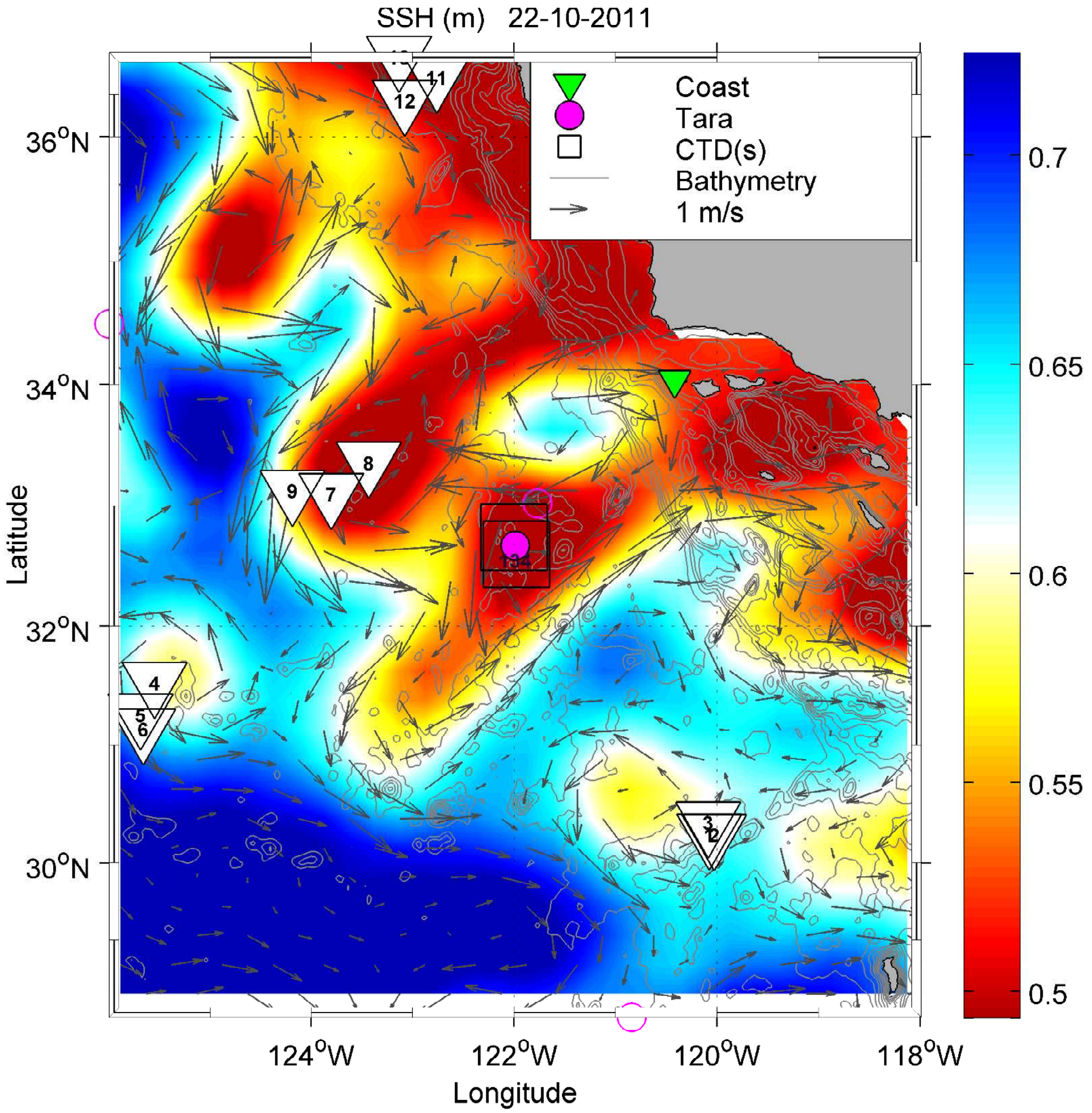

Figure 2: Description: see legend p. 14

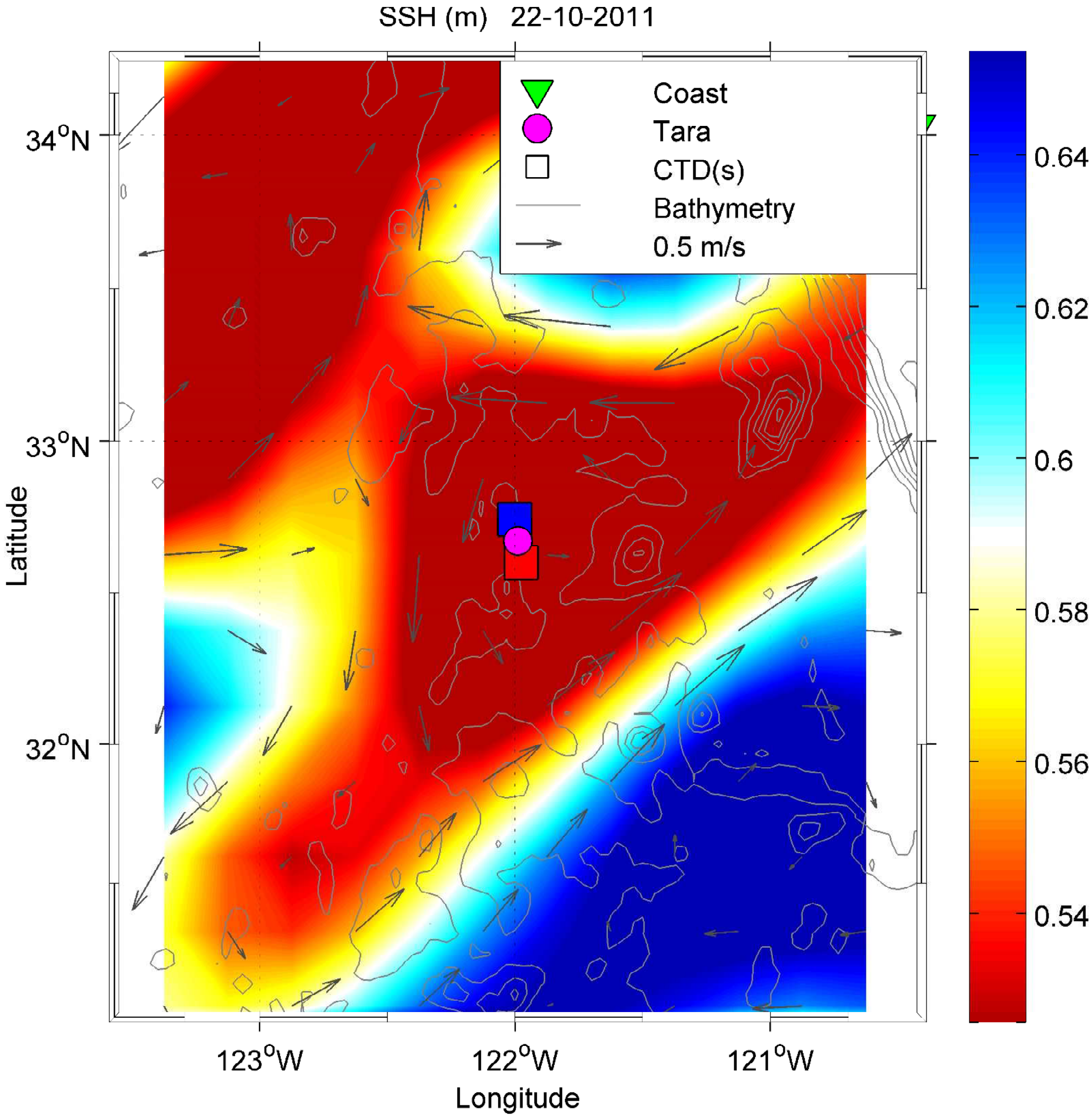

Figure 3: Description: see legend p. 14

1.3 SST maps

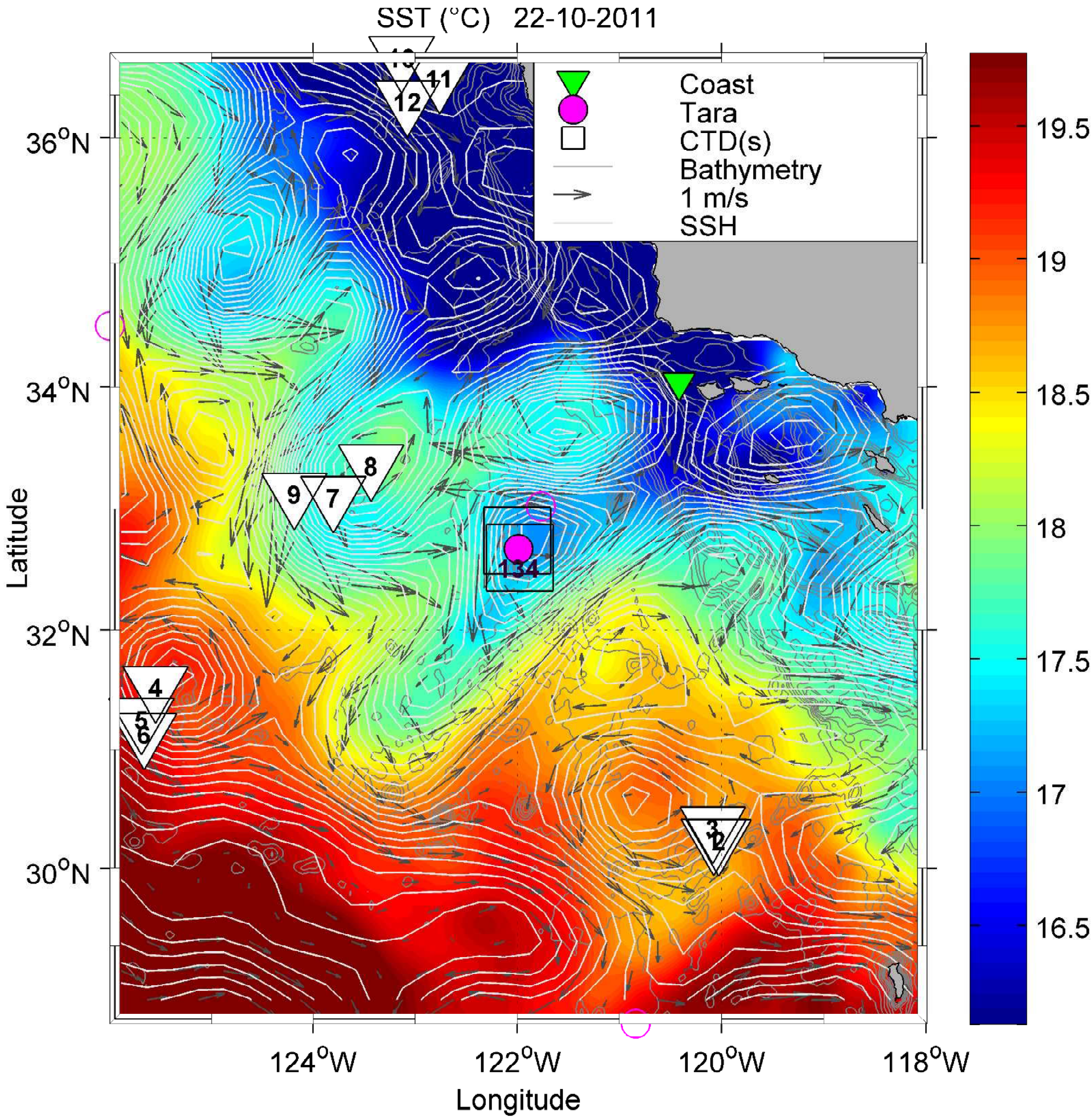

Figure 4: Description: see legend p. 14

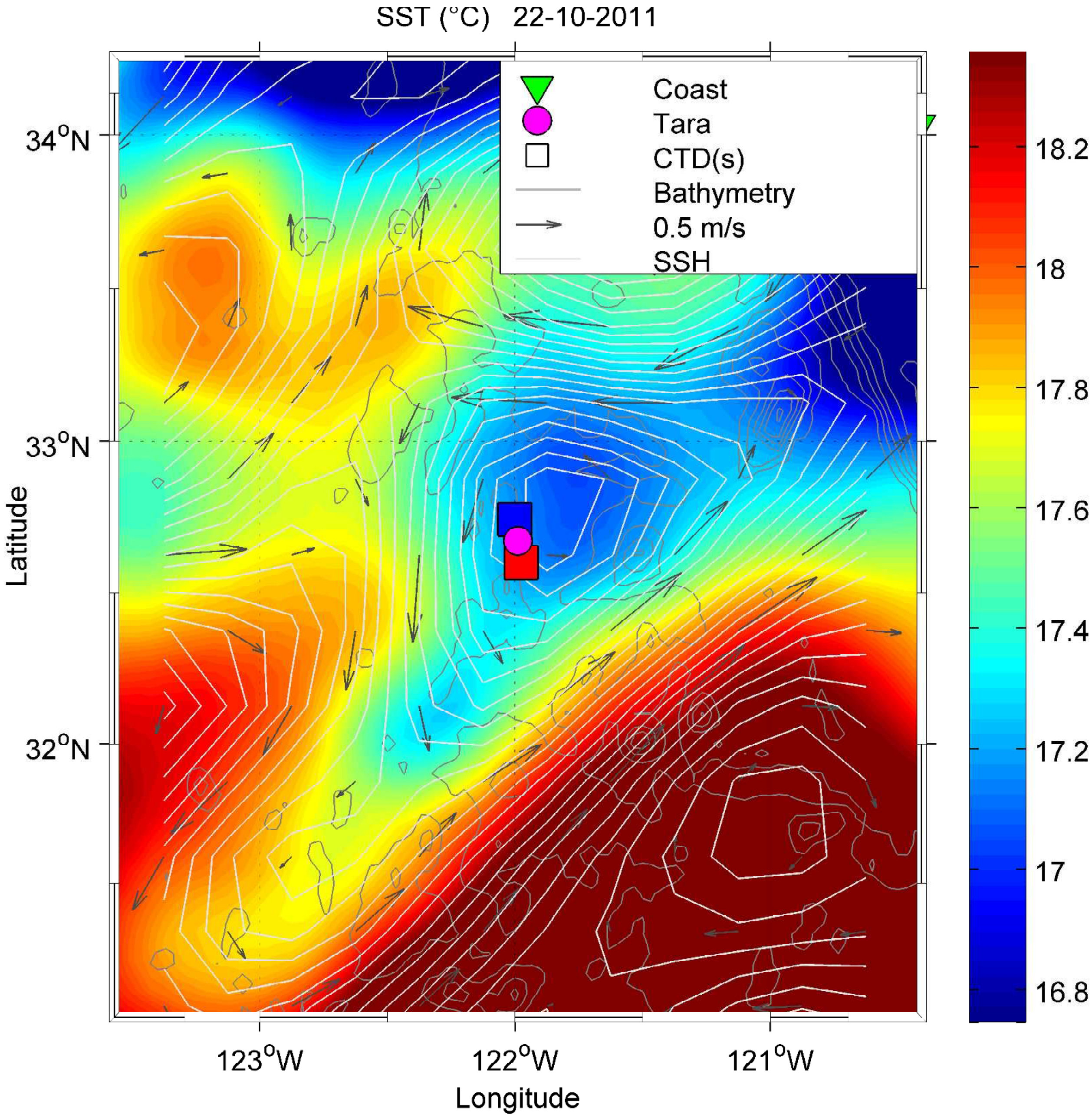

Figure 5: Description: see legend p. 14

1.4 Chlorophyl maps

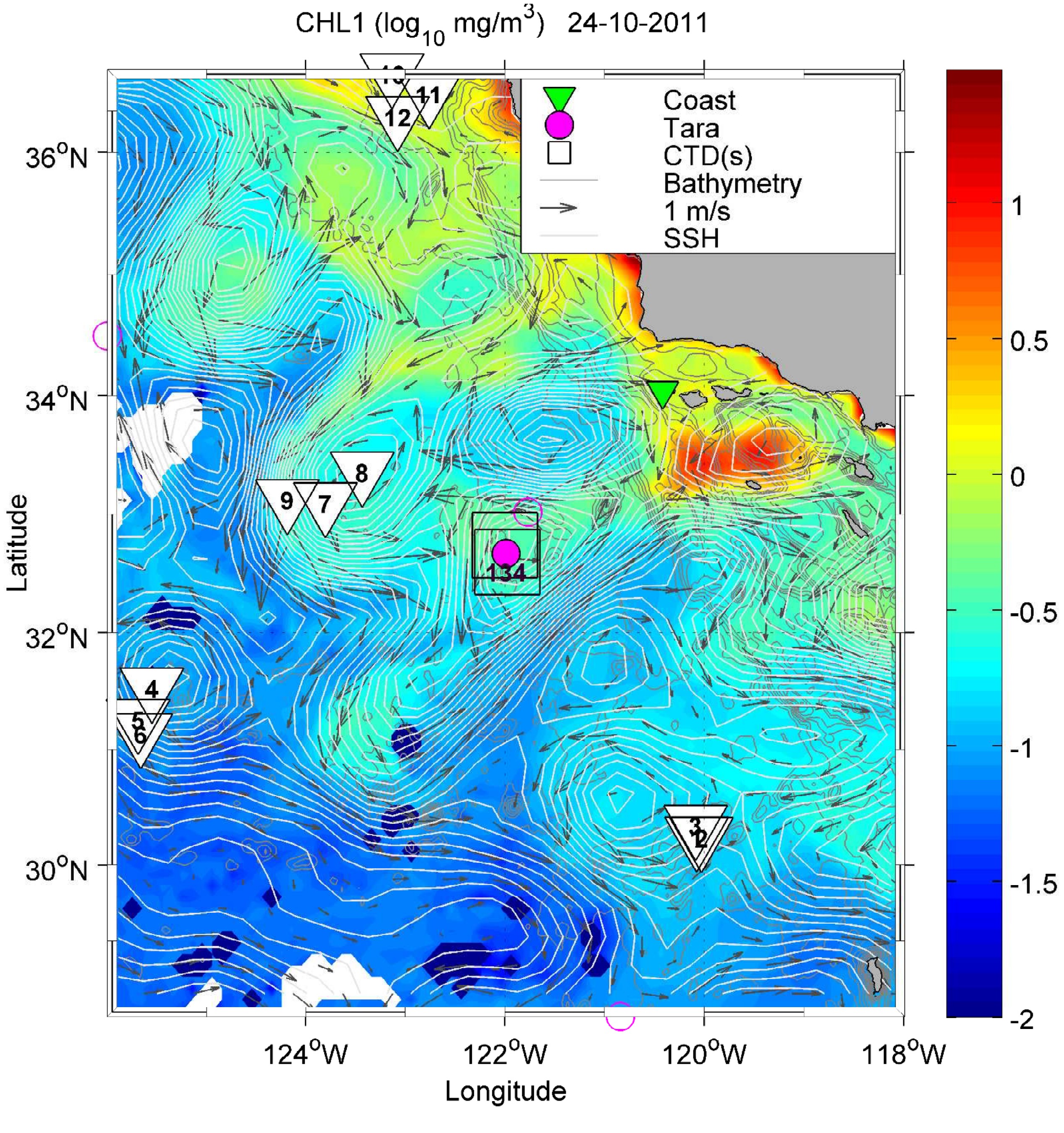

Figure 6: Description: see legend p. 14

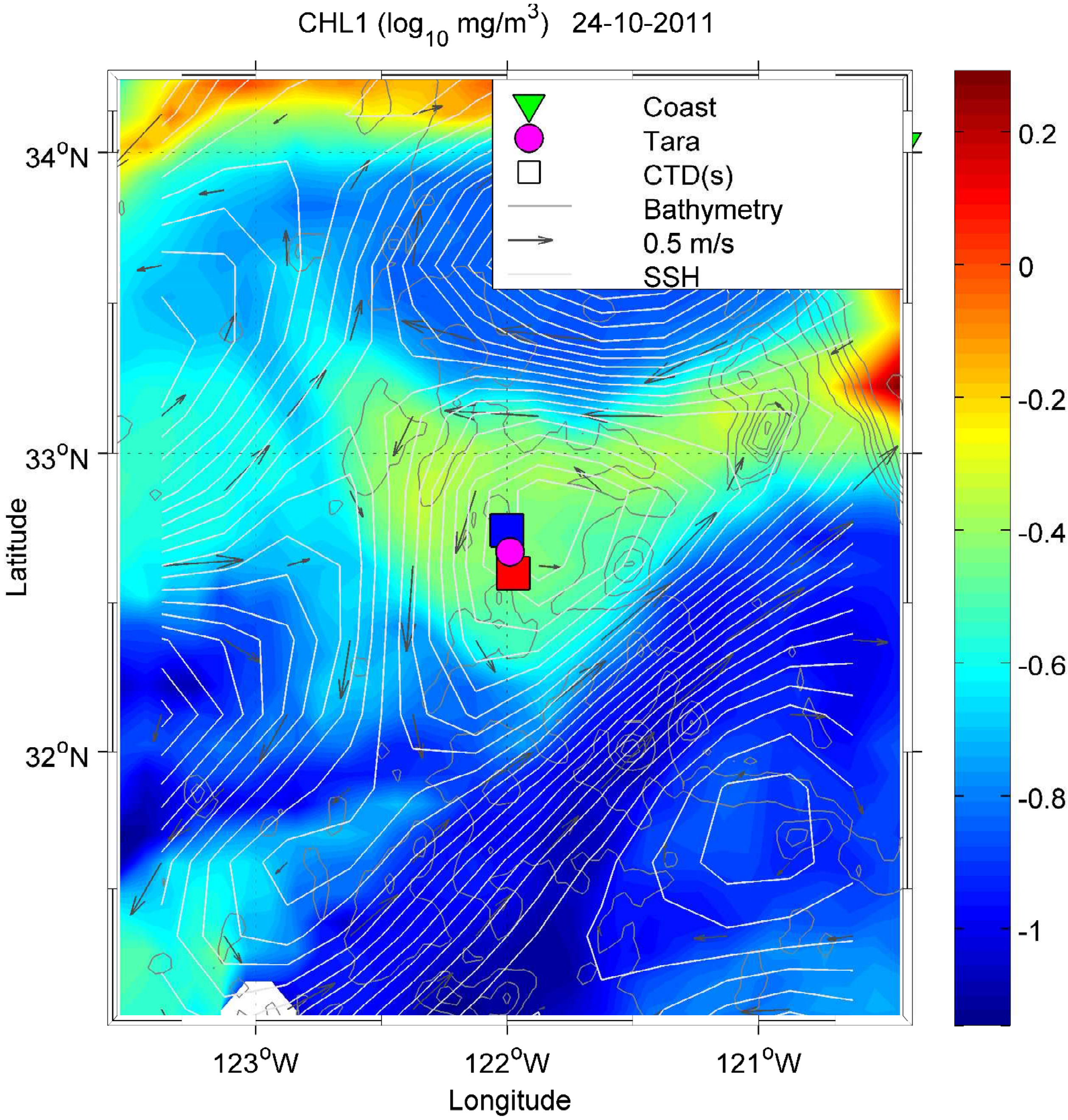

Figure 7: Description: see legend p. 14

2 TSG

2.1 Introduction

To complete the hydrological surface study, we use ThermoSalinoGraph (TSG) data measured by the Tara around the stations. Thermosalinographs are used to collect information about the sea surface, typically in flow-through systems operating continuously throughout a cruise.

We looked for the nearest TSG data available at $\Delta t \pm 15$ *julian days* around Tara stations. TSG data from the TARA OCEAN project (station 1 to 151) are validated but this is not the case of TSG data recorded during the TARA Porlar Cicle project that might present errors.26413 records satisfy these conditions. It is important to emphasize that TSG data are measure along the boat path whereas satellite data are snapshots.

TSG surface temperature is plotted over the Sea Surface Temperature measured by satellite and provided by OSTIA in figure 8.

TSG absolute salinity is plotted over the weekly Sea Surface Salinity data measured by Soil Moisture and Ocean Salinity (SMOS) mission in figure 9. The L3 SMOS data are available on the LOCEAN website (via a request form) but they still experience large biases and noise on various time and space scales. Nicolas KOLODZIEJCZYK work with a team at the LOCEAN to reduce these errors (see Hernandez et al. (2014), Kolodziejczyk et al. (2015b) and Kolodziejczyk et al. (2015a) for more information). These products are not perfect and large biases still exist but they are very promising. He gracefully gave us two types of corrected data for the context of this study:

- The most accurate set of data is composed of weekly map over the Atlantic (between 42N and 42S) with a resolution of 75 km for the period spanning from 2011 to 2013. Corrections are applied to reduce costal, large scale and seasonal orbit biases. An Optimal Interpolation using ISAS Argo interpolated products is performed.
- The other product is the 1/4 2days L3 SMOS data spanning from 30-Jun-2010 to 30-Aug-2014 on which a monthly filter and a systematic coastal bias correction are applied.

The Optimal interpolation product is not available for this station so the L3 band + coastal biais correction is ploted.

2.2 TSG Temperature maps

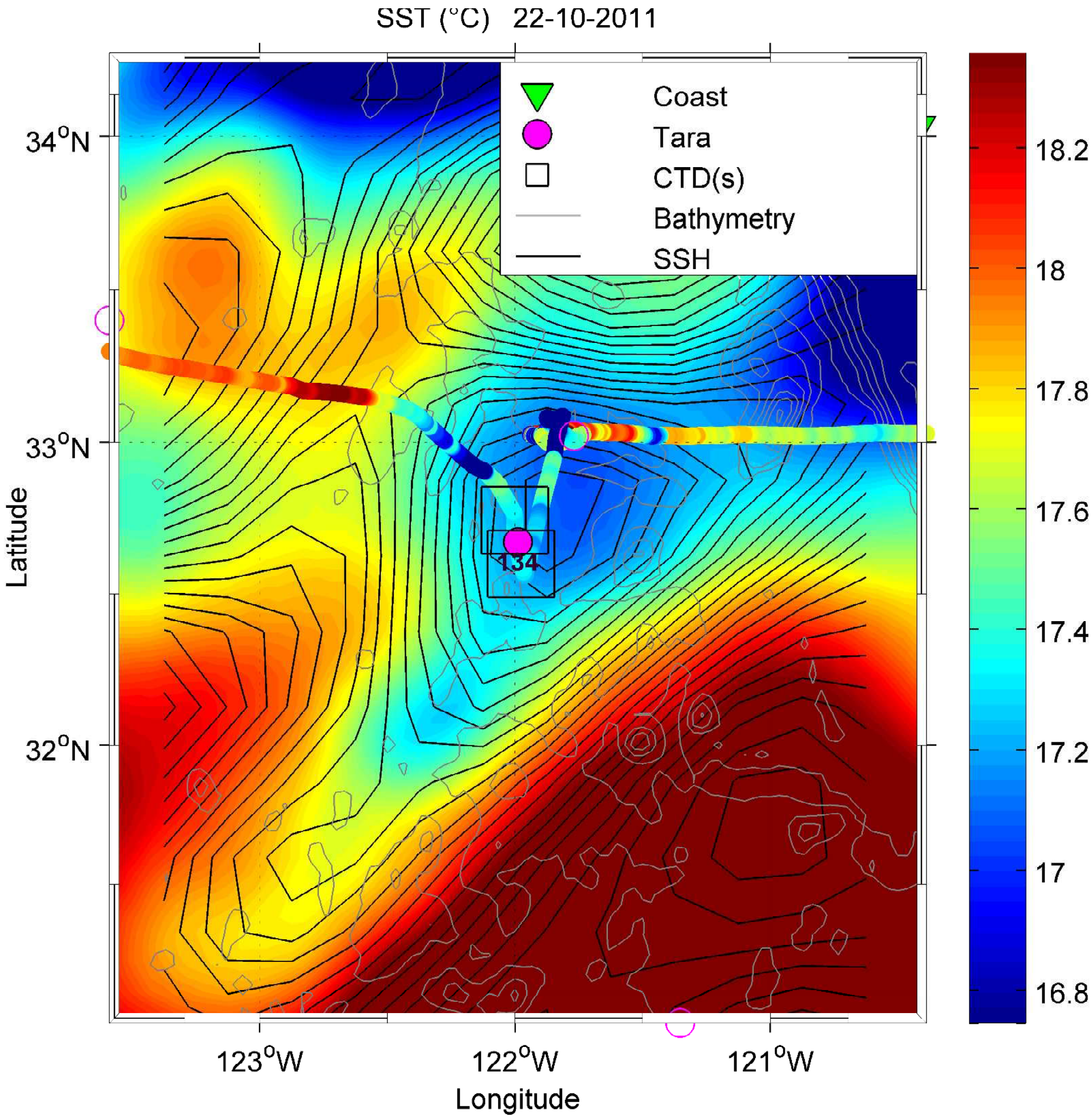

Figure 8: Description: see legend p. 14

2.3 TSG Salinity maps

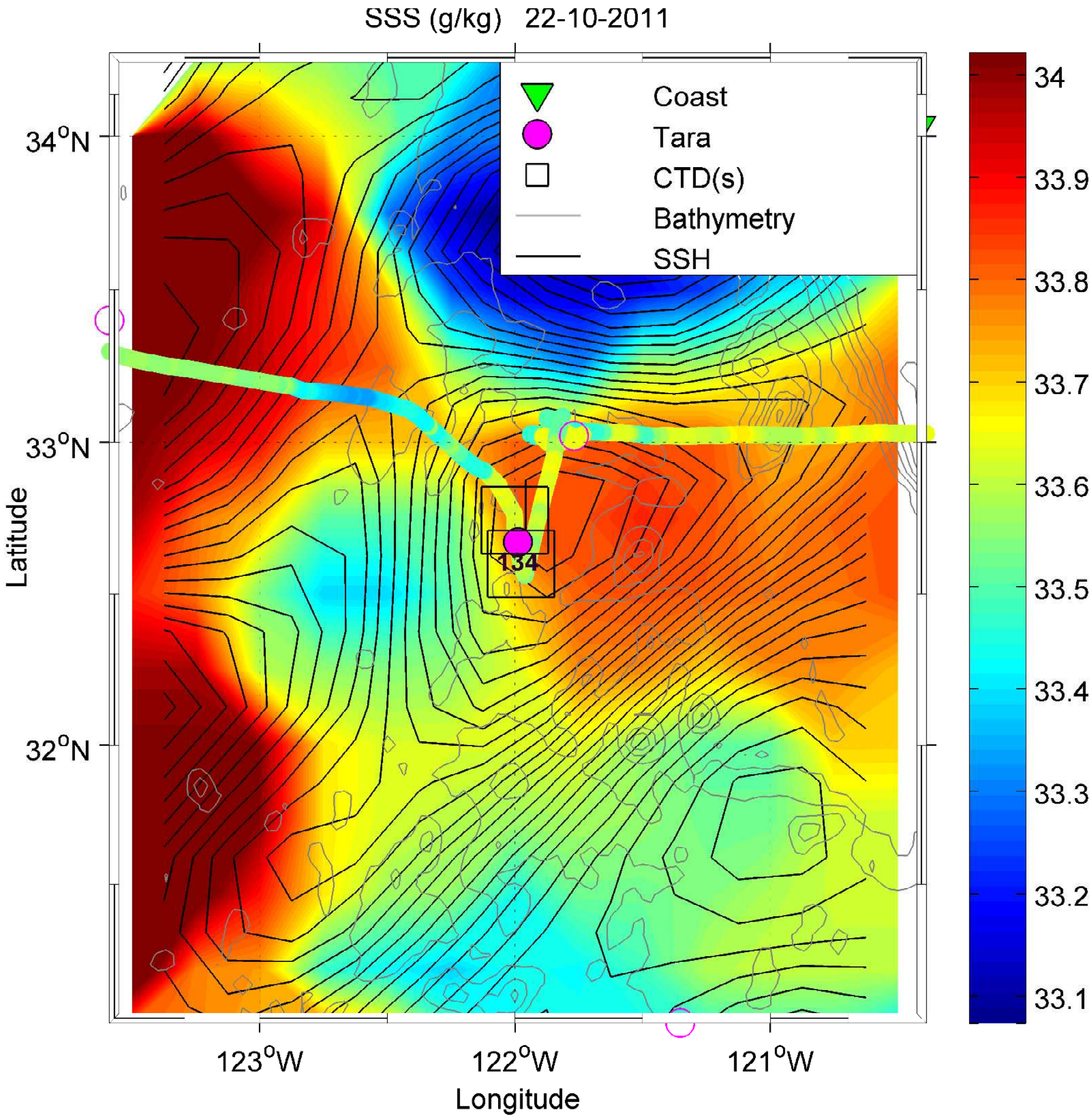

Figure 9: Description: see legend p. 14

3 Conductivity, Temperature and Depth (CTD) measurements

3.1 Introduction

In this study, CTD's measurements have been realized by a `Seabird vertical profiler`. The CTD profiles shown here are provided by the Villefranche Oceanographic Laboratory (LOV), Villefranche-Sur-Mer, France (http://www.obs-vlfr.fr/LOV/ZooPart/Portal/). Moreover, vertical profiles of Nitrate and Oxygen are provided. Additional quantities like salinity or density are then inferred using the Gibbs SeaWater (GSW) Oceanographic Toolbox (`http://www.teos-10.org/pubs/gsw/html/gsw_contents.html`).

For the Tara station n134, 2 CTD profiles are available. We calculate the potential density σ_0 referred to surface and the Brunt-Vaisala frequency (N^2). This one is a pulsation known as the "Brunt-Vaisala frequency" (s^{-2}), and given by:

$$N^2(z) = -\frac{g}{\rho_*}\frac{d\sigma}{dz} \tag{1}$$

where g is the vertical component of gravity, ρ_* a constant density value, d/dz the vertical derivative operator and σ the potential density (we use here σ_0). For more information please refer to Gerkema and Zimmerman (2008) (Eq. 3.18, p. 48 in the book). For each profile, $N^2(z)$ is calculated with a finite differences numerical scheme using $dz = 1m$. When calculated, $N^2(z)$ is averaged with a running median window on $30dbar$ (± 5 $dbar$, centred) to filter noise at small vertical scales (~ 1 m).

We calculate the depth of mixed layer using two definitions given by De Boyer Montégut et al. (2004) to determine the MLD (m). Given a potential temperature profile $\theta(z)$ or a potential density profile $\sigma(z)$, we calculate z for which:

$$|\theta(z) - \theta(10m)| \leq 0.2\ °C \tag{2}$$

$$|\sigma(z) - \sigma(10m)| \leq 0.03\ kg/m^3 \tag{3}$$

Profiles and $\theta - S$ diagrams are presented on Fig. 10 and 11. Colors are used to distinct each CTD profile (dark blue for the first to red for the last one, "jet colorbar-like": dark blue, blue, light blue, cyan, green, yellow, orange, dark orange, red, dark red). Filled circles represent the bottle depths. We give bottles depths, and we calculate the N^2 and fluorescence maximum depths. We give the values of N^2 at all these different depths. Results are given in the Tab. 1

Several indices were computed to describe the context of CTD sampling. A season flag and a position in the season are given for each ctd sample. 4 "submesoscale" structures indices were computed at each ctd location from Satellite data. The intensity of the STT gradient and the intensity of the geostrophic currents are directly understandable. Strain rate is linked to the derivative of geostrophic current [see Waugh et al. (2006)] and Lyapunov exponent (computed by F.D'Ovidio [see d'Ovidio et al. (2004)])is a measure of the presence of a transport front where values in excess of 0.1 day-1 are typically fronts.

Legend In order to relieve figures we describe here their general legend:

- For each CTD we give the Tara's cast's number, CTD number, the bottom depth inferred from `eTopo2` bathymetry product, the distance, azimuth and position of nearest coast point (also inferred from etopo).
- Time information are then presented by giving the date in classic and julian format. Two season indices are presented: the season and the position in this season
- We give the fluo value at Max_{Fluo} depth, and a simple sum of fluo along vertical profile (from 1 to 200m, when possible).
- "Submesoscale" indices computed from satellite data are then presented.

- Ctd properties are then computed at precise depths: MLD_θ, MLD_σ, Max_{Fluo}, Max_{N^2} and each bottle depth.

3.2 CTD profiles

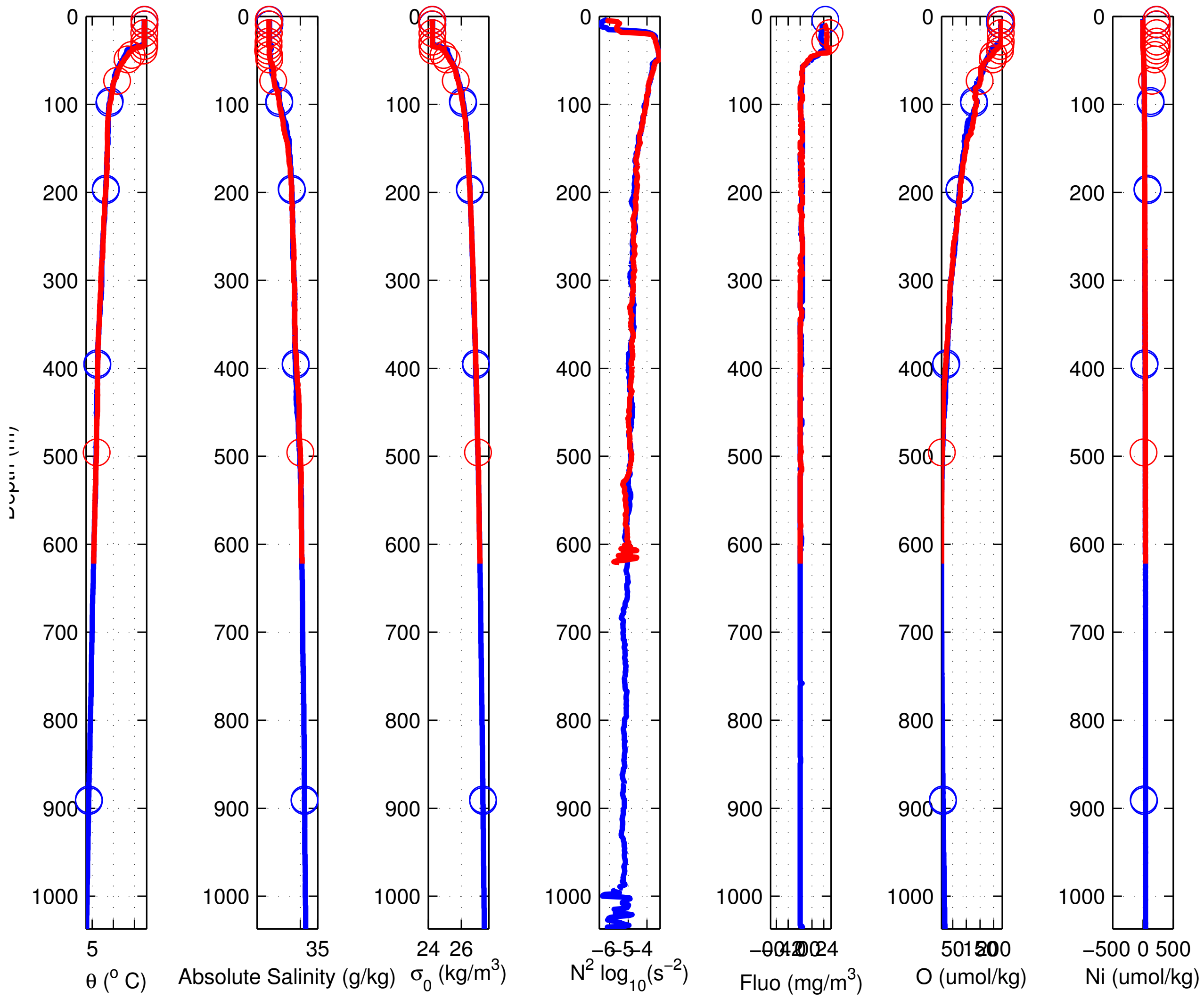

Figure 10: Description: see paragraph p. 14

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3.3 CTD $\theta - S$ diagrams

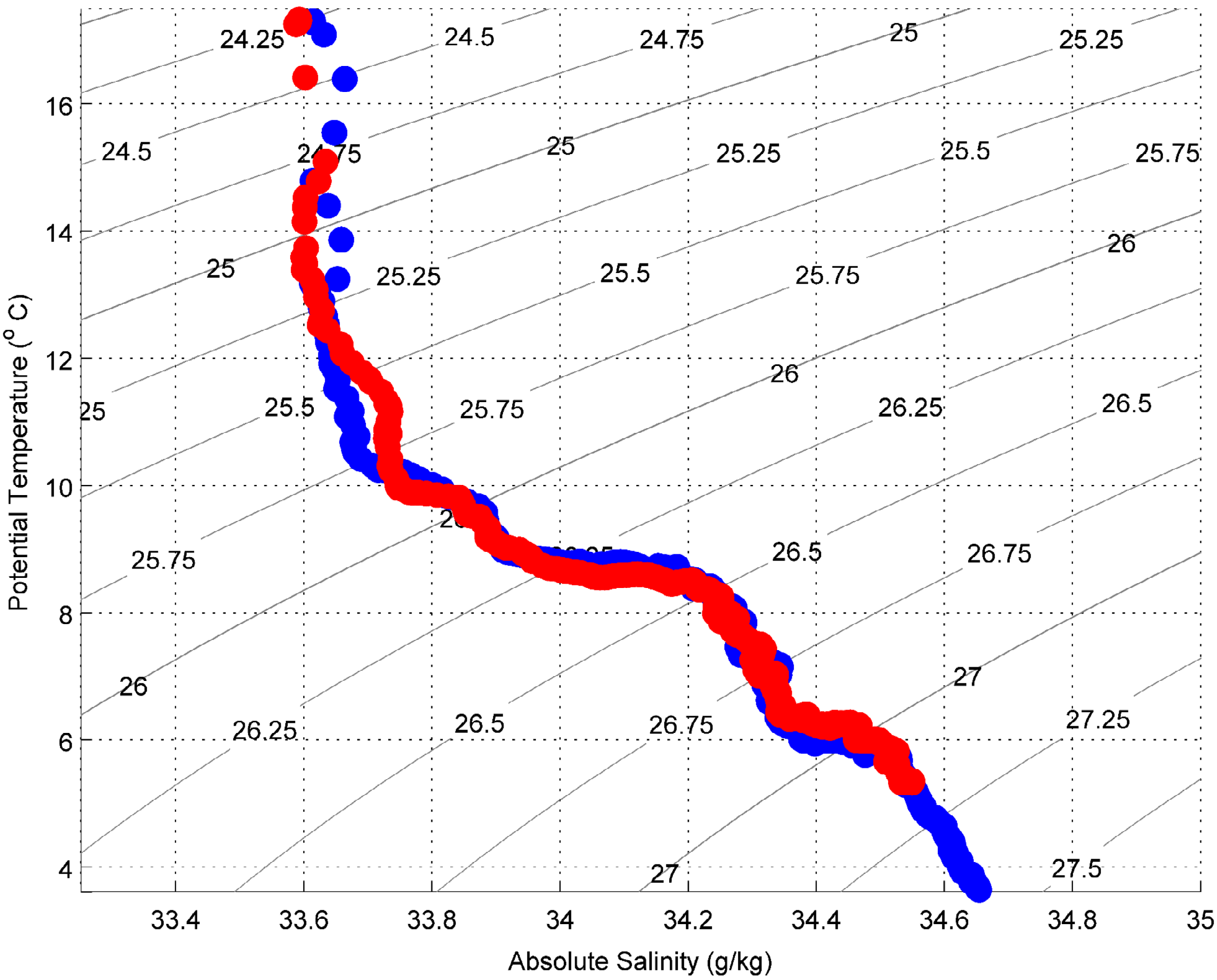

Figure 11: Description: see paragraph p. 14

3.4 Water column characterization from CTD measurements

$Profil$	CTD	Lon	Lat	CTD Depth max (m)	Bathy (m)	Dist[km]/azimuth[°] coast	Lon coast	Lat coast
134	1	-122.0008	32.7425	1037	-4036	206/45	-120.4171	34.0333

Day	Month	Year	Julian day	Core biology Flag	Season	Season part (early-middle-late)
22	10	2011	2455857	1	Autumn	Early

$Max_{Fluo}(mg/m^3)$	Depth (m)	Sum $Fluo$ $1-200m(mg/m^3)$
0.37252	13	57.841

Intensity SST Gradient $(°/100km)$	Intensity Geostrophic current (m/s)	Strain $rate$ (s^{-2})	Lyapunov exponent $(1/days)$
0.70054	0.12102	3.412e-05	0.020941

	Depth (m)	T $(°C)$	AS (g/kg)	σ_0 (kg/m^3)	N^2 (s^{-2})	$Fluo$ (mg/m^3)	O $(\mu mol/kg)$	Ni $(\mu mol/kg)$
$10m$	10	17.3032	33.6142	24.2635	1.5576e-07	0.37252	226.0216	-1.6663
Max	1037	3.7231	34.654	27.4178	NaN	0	21.7754	43.3389
MLD_σ	31	17.2832	33.6141	24.269	0.00030207	0.37044	212.5005	-1.9732
MLD_θ	31	17.2832	33.6141	24.269	0.00030207	0.37044	212.5005	-1.9732
Max_{N2}	41	13.1054	33.6168	25.1833	9.2019e-05	0.33823	188.2092	8.7672
Max_{Fluo}	13	17.3034	33.6142	24.2636	7.1726e-08	0.37252	226.1125	-1.2241
Max_O	13	17.3034	33.6142	24.2636	7.1726e-08	0.37252	226.1125	-1.2241
Min_O	631	5.3046	34.548	27.1595	6.6038e-06	0	9.4508	40.4602
$Depth$ $Nitro$	39	13.1805	33.6124	25.1649	8.2507e-05	0.37586	192.1124	6.1698
B i1	900	4.2022	34.6198	27.3409	6.201e-06	0	15.0552	43.193
B i2	898	4.2078	34.6197	27.3403	1.2049e-06	0	15.257	43.3853
B i3	400	6.2635	34.3545	26.8869	2.2386e-05	0.0078719	27.8014	37.0053
B i4	398	6.2715	34.3536	26.8852	7.4117e-06	0.010628	28.2864	36.775
B i5	200	8.1715	34.2577	26.5436	1.9436e-05	0.040158	73.6436	29.3144
B i6	198	8.1746	34.2557	26.5415	1.0213e-05	0.040949	74.5716	29.2215
B i7	100	8.9628	33.9173	26.1552	8.6837e-05	0.014005	135.4181	22.1144
B i8	98	9.0736	33.9069	26.1295	0.00018535	0.014705	139.5425	22.0236
B i9	10	17.3032	33.6142	24.2635	1.5576e-07	0.37252	226.0216	-1.6663
B i10	5	17.3016	33.6142	24.2637	1.6588e-07	NaN	226.7422	-1.8035

Table 1:

$Profil$	CTD	Lon	Lat	CTD Depth max (m)	Bathy (m)	Dist[km]/azimuth[°] coast	Lon coast	Lat coast
134	2	-121.9759	32.6002	622	-4089	216/42	-120.4171	34.0333

Day	Month	Year	Julian day	Core biology Flag	Season	Season part (early-middle-late)
22	10	2011	2455857	1	Autumn	Early

$Max_{Fluo}(mg/m^3)$	Depth (m)	Sum $Fluo$ $1-200m(mg/m^3)$
0.44761	29	57.841

Intensity SST Gradient $(°/100km)$	Intensity Geostrophic current (m/s)	Strain $rate$ (s^{-2})	Lyapunov exponent $(1/days)$
0.6662	0.10125	2.3596e-05	0.020941

	Depth (m)	T $(°C)$	AS (g/kg)	σ_0 (kg/m^3)	N^2 (s^{-2})	$Fluo$ (mg/m^3)	O $(\mu mol/kg)$	Ni $(\mu mol/kg)$
$10m$	10	17.3235	33.5928	24.2423	8.7411e-06	0.42044	227.5781	-0.75413
Max	622	5.3827	34.549	27.151	NaN	0	9.2515	41.0657
MLD_σ	34	17.2557	33.5877	24.2555	0.0009954	0.4474	225.2682	-1.0333
MLD_θ	34	17.2557	33.5877	24.2555	0.0009954	0.4474	225.2682	-1.0333
Max_{N2}	44	13.3965	33.5995	25.1119	0.00028216	0.26722	193.1894	8.7642
Max_{Fluo}	29	17.2947	33.5917	24.2491	1.9814e-06	0.44761	228.0289	-0.79871
Max_O	14	17.3097	33.5928	24.2458	5.7864e-06	0.44095	228.0506	0.0029719
Min_O	620	5.3899	34.549	27.1501	1.6976e-06	0	9.2043	40.8451
$Depth$ $Nitro$	37	14.7884	33.6229	24.8401	0.00047401	0.49597	213.4054	0.78712
B i1	500	5.9892	34.5009	27.0379	6.8981e-06	0	11.6307	39.0922
B i2	75	10.0011	33.7461	25.8529	0.00012521	0.02125	149.5347	19.7484
B i3	50	12.5287	33.6246	25.3024	0.0001632	0.1299	173.6876	12.3113
B i4	45	13.2455	33.6129	25.1524	0.00037533	0.2113	190.4972	8.5087
B i5	40	14.152	33.6009	24.9578	0.00065826	0.49597	199.5557	4.9418
B i6	35	16.4178	33.602	24.4579	0.0025817	0.44761	213.0854	-1.2078
B i7	30	17.2923	33.5915	24.2495	6.2561e-06	0.4474	226.9835	-0.70517
B i8	20	17.3034	33.5928	24.2475	5.083e-07	0.45271	228.8504	-0.74331
B i9	10	17.3235	33.5928	24.2423	8.7411e-06	0.42044	227.5781	-0.75413
B i10	5	17.3226	33.5927	24.2423	1.3528e-06	NaN	227.4143	-0.12527

Table 2:

4 ARGO

4.1 Introduction

To complete the CTD study, we use ARGO data available around Tara's stations. ARGO is a global array of autonomous profiling floats that observe pressure, temperature and salinity in the upper $2000m$ of the ocean. These data were collected and made freely available by the International Argo Program and the national programs that contribute to it (http://www.argo.ucsd.edu, http://argo.jcommops.org).

The Argo Program is part of the Global Ocean Observing System. The ARGO profiles were downloaded on the Aviso ftp web site where only pressure (P), temperature (T), and salinity (S) data. However, some of these profiles were still suspicious so applied another analysis in the same way that Chaigneau et al. (2011) using the following conditions:

- Data flagged as good and probably good (Argo quality flag 1 and 2)
- The shallowest data above 15 dbar and the deepest data below 300m
- A difference of pressure level inferior than 25 dbar between 0-100dbar and inferior than 50 dbar between 100-300dbar

We looked for the nearest ARGO floats available in box defined by $\Delta X \pm 4^{\circ}$ $lat - lon$ and $\Delta t \pm 15$ $julian\ days$ around Tara stations. For each CTD profile we search for the best matching ARGO profile. We computed distance dx, delay time dt, and radius $r = \sqrt{dx^2 + dt^2}$ between each ARGO and CTD profiles. We add correlations calculations between CTD-ARGO salinity and temperature. Correlations are calculated using the `corrcoef` function in `Matlab`. To make correlations calculation possible we interpolate ARGO profiles (defined on the 152 levels vertical grid) on a CTD-compatible 1 decibar vertical grid. We present the results in Tab. 3 with the ARGO profiles we kept after tests. We show the CTD and **all** ARGO profiles on Fig. 12, and a $\theta - S$ diagram on Fig. 13.

4.2 Correlations with CTD profiles

CTD	Argo	*Radius*	*dt* (*jul*)	*dx* (*km*)	θ correl.	*S* correl.	Lon Argo	Lat Argo
1	1	331.9718	14	331.6764	0.98748	0.95602	-120.077	30.255
1	2	334.6536	4	334.6297	0.97691	0.95514	-120.028	30.251
1	3	321.7423	-7	321.6661	0.97676	0.96415	-120.087	30.357
1	4	359.8358	13	359.6009	0.96207	0.96299	-125.541	31.538
1	5	383.8891	3	383.8774	0.95708	0.93674	-125.679	31.271
1	6	388.071	-8	387.9885	0.98146	0.9743	-125.653	31.147
1	7	173.8063	15	173.1579	0.99581	0.99116	-123.801	33.112
1	8	150.6152	4	150.562	0.99795	0.99524	-123.431	33.369
1	9	208.6801	-7	208.5627	0.98982	0.9911	-124.183	33.138
1	10	447.0367	14	446.8174	0.97341	0.96926	-123.133	36.647
1	11	422.2752	3	422.2645	0.96633	0.98463	-122.76	36.484
1	12	408.2036	-8	408.1252	0.97789	0.98269	-123.077	36.3
2	1	317.6131	14	317.3044	0.9901	0.94043	-120.077	30.255
2	2	320.3629	4	320.3379	0.97315	0.94207	-120.028	30.251
2	3	307.4987	-7	307.419	0.9707	0.95608	-120.087	30.357
2	4	356.702	13	356.465	0.95193	0.95344	-125.541	31.538
2	5	379.8208	3	379.8089	0.94333	0.91803	-125.679	31.271
2	6	383.4617	-8	383.3782	0.97901	0.96806	-125.653	31.147
2	7	180.5475	15	179.9233	0.99582	0.98406	-123.801	33.112
2	8	160.6241	4	160.5743	0.99811	0.99471	-123.431	33.369
2	9	214.9773	-7	214.8633	0.98802	0.98934	-124.183	33.138
2	10	462.9855	14	462.7738	0.96261	0.94823	-123.133	36.647
2	11	438.2812	3	438.271	0.94482	0.97257	-122.76	36.484
2	12	424.1431	-8	424.0676	0.96507	0.97045	-123.077	36.3

Table 3: Description: see paragraph p. 18

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4.3 ARGO and CTD profiles

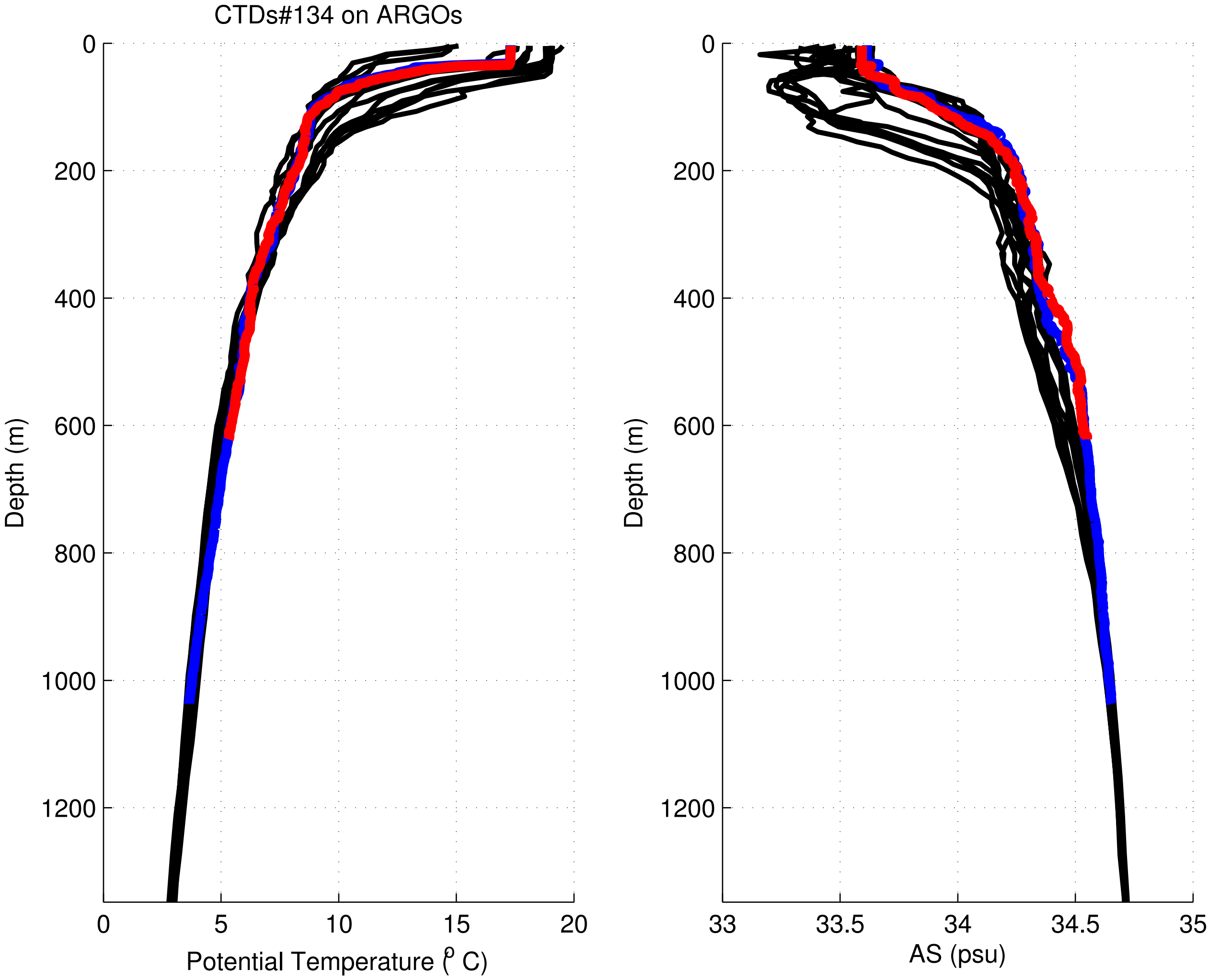

Figure 12: Description: see paragraph p. 18
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4.4 ARGO and CTD $\theta - S$ diagrams

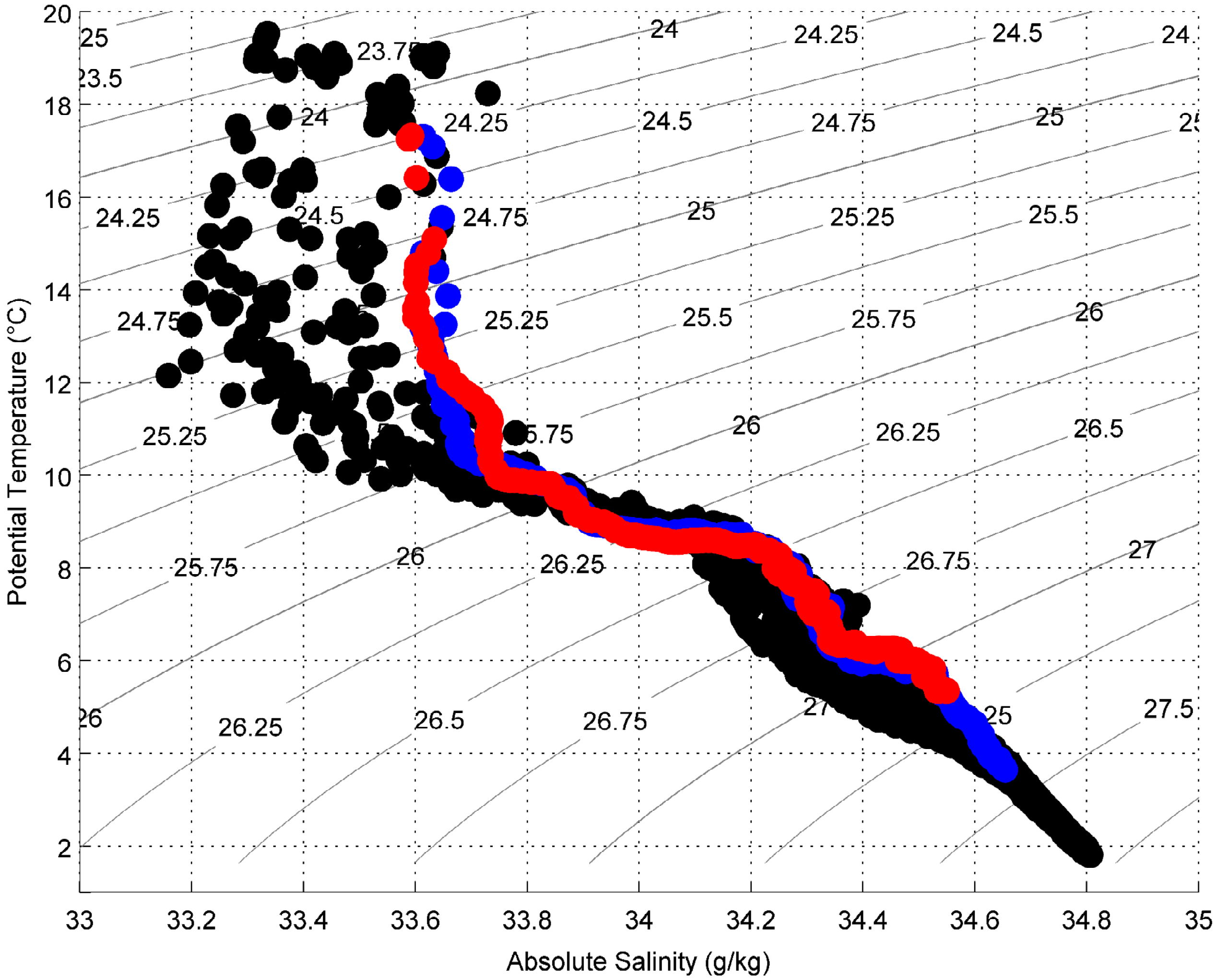

Figure 13: Description: see paragraph p. 18

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