KESS Data Report – WHOI subsurface moorings

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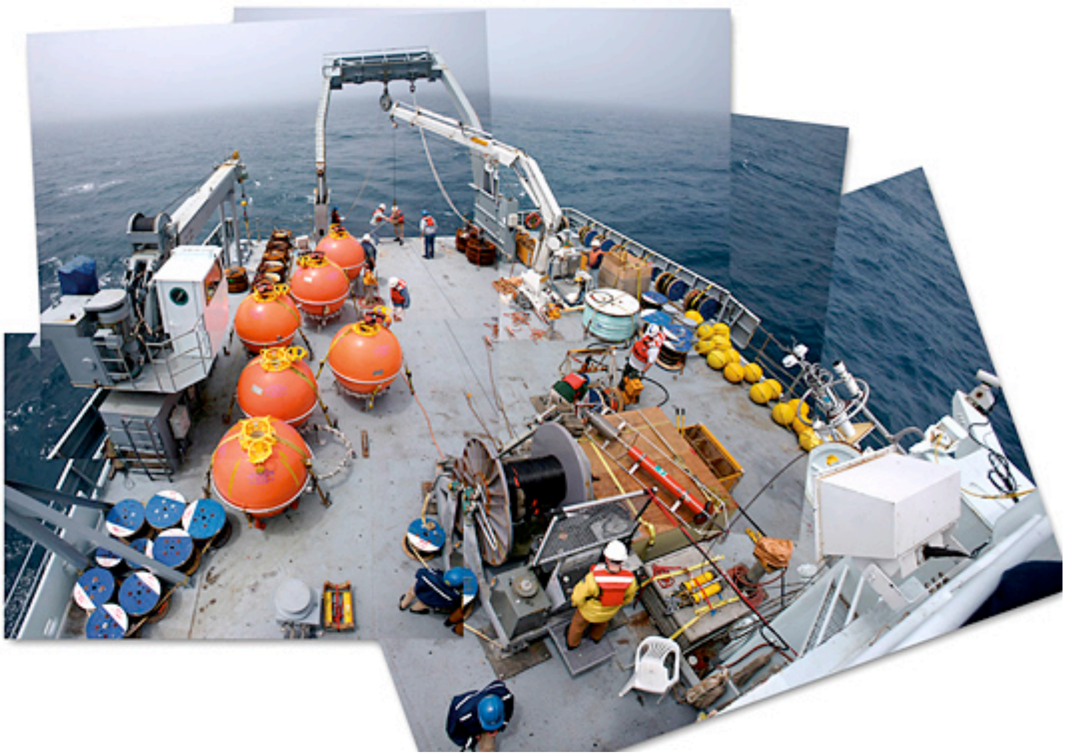

1 Data files

The processing of the data from the WHOI subsurface moorings is presented in this document. In particular, these data files are explained:

- **adcp_Y1.zip** and **adcp_Y2.zip**: Files containing the raw and processed ADCP data.
- **mmp_Y1.zip** and **mmp_Y2.zip**: Files containing the processed moored profiler data.
- **vacms_basics.tar.gz**: File containing the VACM data.
- **cm1_basic_120107.tar.gz** and **cm2_basic_120107.tar.gz**: RCM data files, and Aquadop.
- **currents_K*Y*.mat**; All the current meter data (all except MMPs) including estimate of mooring motion.

2 Mooring positions and design

Mooring positions for year 1 (2004-2005)

KESS 1*	37° 04.186' N	147° 22.716' E
KESS 2	36° 18.356' N	146° 53.626' E
KESS 3	35° 32.836' N	146° 25.619' E
KESS 4-1*	34° 46.858' N	145° 55.150' E
KESS 4-2	35° 10.720' N	146° 12.690' E
KESS 5	34° 01.623' N	145° 31.293' E
KESS 6	33° 14.491' N	145° 02.016' E
KESS 7	32° 23.998' N	144° 33.201' E

Mooring positions for year 2 (2005-2006)

KESS 1	37° 04.172' N	147° 22.253' E
KESS 2	36° 21.696' N	146° 51.057' E
KESS 3	35° 32.755' N	146° 24.787' E
KESS 4	34° 50.916' N	146° 00.959' E
KESS 5	34° 01.951' N	145° 30.327' E
KESS 6	33° 17.339' N	145° 02.614' E
KESS 7	32° 24.334' N	144° 35.578' E
KESS 8	34° 49.803' N	144° 59.950' E

*In the first year, KESS-1 and KESS 4-1 only have the deep RCMs (top of mooring broke off during deployment).

Most moorings consisted of a subsurface float at 250 m with a up-looking ADCP, a moored profiler sampling from 260 m to 1500 m every 15h, a VACM at 1500m, and 3 RCMs at 2000, 3500, and 5000 m. (Fig. 1)

The Kuroshio Extension Observatory (KEO) mooring, a surface mooring maintained by PMEL (Meghan Cronin) was anchored at 32° 21.0' N & 144° 38.2' E and has a watch circle of about 5 km. It is always located within 10-15 km of KESS-7 (Fig. 2). More details and data at http://www.pmel.noaa.gov/keo/

Data return was fairly good (Fig. 3) The current meters at 1500, 2000, 3500, and 5000m, and the ADCP (0 to 250 m) yielded almost complete time series at all sites (>80% data return), while the MMPs had some problems. Typically the MMPs worked after deployments in 2004 and 2005, but stopped profiling in strong currents and some had mechanical failures in winter months. For sites occupied for two consecutive years, the MMPs returned measurements at any given depth (250-1500 m) and any given day 55% of the time, with rates as high as 72% one of the given site.

3 ADCPs

3.1 Instruments

ADCP year 1 (2004-2005)

KESS 1	No ADCP, top of mooring broke off on deployment and was recovered immediately.
KESS 2	BroadBand #1635, partial record.
KESS 3	BroadBand #1594
KESS 4-2	BroadBand #1622 (U of Hokkaido)
KESS 5	BroadBand #1619
KESS 6	WorkHorse #5091
KESS 7	NarrowBand #461 (PMEL), with temperature/pressure recorder next to it (TP11156)

ADCP year 2 (2005-2006)

KESS 1	WorkHorse #5091
KESS 2	NarrowBand #461 (PMEL) ****no good velocity data****
KESS 3	BroadBand #1594
KESS 4	LongRanger
KESS 5	BroadBand #1635
KESS 6	WorkHorse #1969
KESS 7	NarrowBand #542 (PMEL), with temperature/pressure recorder next to it (TP11156)
KESS 8	No ADCP

All the raw and processed data are in the files called **adcp_Y1.zip** and **adcp_Y2.zip**. These files contain:

- **cfg**: Structure containing all the configuration of the ADCP.
- **adcp**: Structure containing all the data recorded by the ADCP.
- **map**: Structure containing

cfg and **adcp** were obtained by reading the RD files into matlab using the routines originally written by R. Pawlowicz (rich@eos.ubc.ca):

```
[adcp,cfg]=rdradcp('binary_file',1,-1);
```

map is the gridded data, where each bin was mapped to its real depth, taking into account the vertical motion of the mooring. This requires a knowledge of the actual depth of the ADCP. The next section addresses this problem. Time is still the original time of each ensemble. Some quality control is also done when mapping on the regular depth grid:

```
abs(adcp.error_vel)<=0.5
abs(adcp.vert_vel)<=2
abs(adcp.east_vel)<=4
abs(adcp.north_vel)<=4
```

3.2 Pressure time series for the ADCPs

In order to map the velocities of the ADCP into a regular depth-time grid, we need to know the depth of the sphere. Unfortunately, none of the ADCPs have pressure recorder (although they have temperature). Only at KESS 7, we have the PMEL TP which was right next to the NB ADCP. This makes it easy for this one (Fig. 4). The tidal signal (semidiurnal + diurnal) can be very big, much bigger than the changes in barotropic elevations (Fig. 6).

The other moorings are a little bit more tricky. Fortunately, most of the remaining moorings we had broadband ADCPs (or Narrowband), which have a signal that reached the surface (in general). By fitting the echo of the surface, we can find relatively precisely the range to the surface (Fig. 5). Averaging the ranges from the 4 beams, we get a reasonably good estimate of the depth of the ADCP (Fig. 6). Comparison with the minimum pressure of the MMP is good.

The results of this fit are added to the variable **adcp** (e.g. adcp.sfc1 are the fit parameters for beam 1). The depth of the instrument (calculated from a conditional average of the first parameter of the fit) is saved as

- **adcp.depth**: Time series of the depth (in m) of the ADCP transducers.

Comparing the 30-min estimate of the range to the surface with the barotropic tide (Fig. 6), we find that the variations can be up to 10 m over a semidiurnal cycle, and that, at least for the month plotted here, these are in phase with the barotropic elevations (although those are only 0.5 m at the most). The correspondence with the magnitude of the currents (presumably tilting the mooring) is not as good. Although a little strange, this might be due to a mean current, which is sometime weakened by the tide, and sometime made stronger.

At times when the currents are really strong, the surface can get out of the range of the ADCP. In those instances, we used the MMP pressure data to patch the time series. Excursions can reach over 300 m at times, meaning that the sphere is below 550m! That's also what we use for the moorings with WorkHorse ADCPs.

Knowing the depth of the instrument, we can map the ADCP data onto a regular depth grid. These are shown in Fig. 8, where the excursions due to the currents are evident.

The currents, averaged between 150 and 250 m and over a period of 1 day, are shown in Fig. 9a for all the moorings (vectors are plotted every 5 days). Gaps are present when the tilt of the mooring, affecting both range and quality, is too strong. These can be compared with the surface currents inferred from the SSH from altimetry (Aviso maps), shown in Fig. 9b for the same time and position as the direct measurements. The large-scale features are similar.

4 MMPs

4.1 Instruments

MMP year 1 (2004-2005)

KESS 1	No MMP.
KESS 2	#119
KESS 3	#117
KESS 4-2	#107
KESS 5	#109
KESS 6	#118
KESS 7	#110, profiled continuously for 3 weeks in Jan 05.

MMP year 2 (2005-2006)

KKESS 1	#117
KESS 2	#119
KESS 3	#116
KESS 4	#101
KESS 5	#102
KESS 6	#103
KESS 7	#108
KESS 8	#109

MMP processed data are in the files called **mmp_Y1.zip** and **mmp_Y2.zip**. For each mooring there is a file called **MMP_profiles_K*.mat**, which contains all the data on a regular depth grid, a non-regular time grid, and corrected velocities. These files are made of a structure called **mmp** that include:

- **time**: start time of the profile
- **depth**: regular depth to which the raw data have been interpolated.
- **U**, **V**: corrected east and north velocity.
- **W**: vertical velocity of the profiler (not corrected, not the oceanic w)
- **T**, **S**: temperature and salinity profiles.
- **THET**, **SIGTH**: potential temperature and potential density profiles.
- **timee**: end time of the profile.
- **profile**: is the profile number.
- **pmin** and **pmax**: the min and maximum pressures.
- **tmin** and **tmax**: the temperature at the min and max pressures.
- **U_uncorrected**, **V_uncorrected**: uncorrected velocities, just for reference.

Temperature, salinity, density, potential temperature were quality controlled and processed by Maggie Cook (WHOI). Velocities have been corrected by comparing with the other instruments. Amplitude is multiplied by a factor of 1.3333, and compass direction is adjusted. The speed correction was found by comparing different instruments located directly above or directly below the MMPs. For example, Fig. 10 shows the comparison of the speed recorded by the ADCP (<250 m), a VACM deployed just below the sphere ($\sim$ 260 m, and the MMP at the top of its profile during the first year at KESS-4. There is a clear bias, and taking the vertical shear into account doesn't change the answer.

When all the data are considered (comparing with ADCP at the top, and the VACM at the bottom), we find that the best agreement is obtained by multiplying the MMP speeds by 4/3.

Compass calibration are calculated via a least square fit, minimizing the difference between the velocity measurements from the MMP and the ADCP at the top, and the VACM at the bottom. This is a noisy estimate, but the data then fit reasonably well.

```
theta(year, mooring)=[[NaN -18 -18 -20 -20 -16 -24 NaN]; ...
                      [-15 -18 -14 -12 -10  -8 -70 -82]];
correction = 1.3333*exp(-i*theta*pi/180)*(U_i*V)
```

Velocity measurements from the MMPs are known to be tricky and somewhat problematic (FSI instrument ?). I believe that John Toole is now using a different velocity sensor.

Note: the compass was known to be off for a few moorings (KESS-7, KESS-8) in the second year. Also, in no case did we expect a small offset, so these numbers are not necessarily worrisome. However, *MMP velocity measurements should not be trusted too much...* A quantification of the error would be good...

5 Deep current meters

5.1 VACMs

The data file **vacms_basics.tar.gz** includes one file for each mooring deployment. Naming convention for these is **K** - year [1 or 2] - mooring [1-8] - **vacm.mat**.

Content of these files is self-explanatory. Most of the VACM data are at 1500 m, but some moorings had an additional one above the MMPs. The VACMs have pressure and temperature sensors.

5.2 RCMs

The Andeeraa RCM-11 data are found in **cm1_basic_120107.tar.gz** and **cm2_basic_120107.tar.gz**. Naming convention is **K** - year [1 or 2] - mooring [1-8] - **rcmfx.mat**.

The RCMs have no pressure sensor, but temperature is recorded (although not with a very good resolution). The speeds have been adjusted for the local speed of sound and multiplied by 1.1 (Hogg and Frye, JPO 2007).

RCM data zip files also contain **K17aqdfx** and **K28aqdfx.mat**, which are the data file from the Nortek Aquadop. This instrument has a pressure and a temperature sensors.

Year 1 RCMs are 30 minutes but Year 2 RCMs are a mix of 30 and 60 minutes because of the lack of availability of high capacity batteries. The AquaDopps sampled at 15 minutes. No mooring motion correction has been applied to deep current meter data in these files.

Currents below the thermocline are only weakly depth dependent, implying the circulation is largely barotropic.

6 Higher level processing

6.1 currents_K[1-8]_Y[1-2]

Files with all the current data available for a particular mooring (i.e. all except MMP data). The depth time series of each instrument was calculated from our best estimate of the mooring motion. 30-min sampling period.

Find the depth of each instrument (mooring motion) and radius of motion. We know the bottom depth (mooring log). If there is 2 or more pressure time-series, we use a 3rd degree polynomial representing the mooring shape: e.g. depth of RCM at ($z0$ =2000 m) =

```
P(1,:).*z0.^2+P(2,:).*z0+P(3,:);
```

A linear fit is (P(1,:)=0) for 1 pressure time series. R is the horizontal distance that the sphere moved, assuming that polynomial.

Put all the instrument on a common time - same for all moorings (from 1 Jun 2004 to 30 Jun 2005, or from 1 Jun 2005 to 30 Jun 2006).

The structure of these files are similar to that of the raw data.

- **time**: regular time vector
- **adcp**: map of the adcp data.
- **vacm**: structure of the vacm data, as before, including depth.
- **rcm**: structure of the rcm and aqd data, as before, now including depth of the instrument.
- **lat, lon**: Anchor position.
- **U_BT**: Barotropic tide at the mooring location from TPXO 6.2 model
- **P**: Mooring motion, polynomial fit
- **R**: Horizontal displacement of the sphere from its vertical (straight) position.

Velocity measurements are not corrected for horizontal motion of the mooring.

The data linearly interpolated on a regular 30-min time vector.

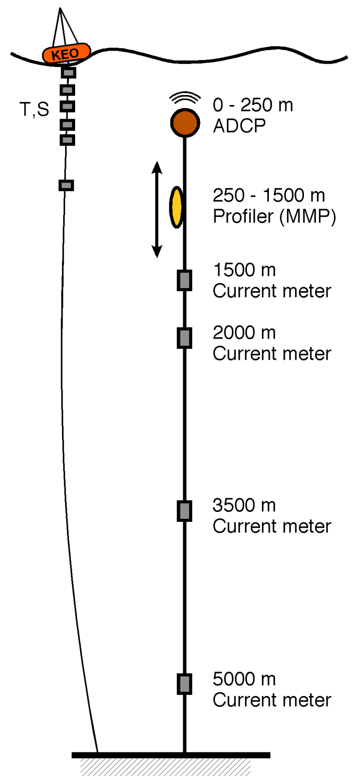

Figure 1: Schematic of a KESS subsurface mooring and of KEO (close to KESS-7)

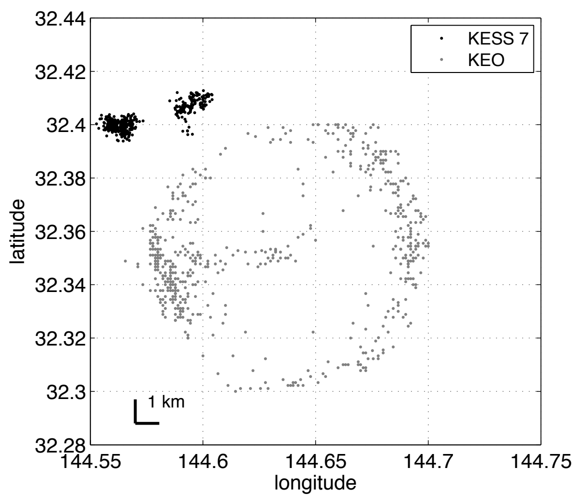

Figure 2: Position of KESS-7 (black) and KEO (gray) for the 2 years. The position of the subsurface mooring is estimated by estimating the horizontal displacement corresponding to the vertical motion we observe (see next section).

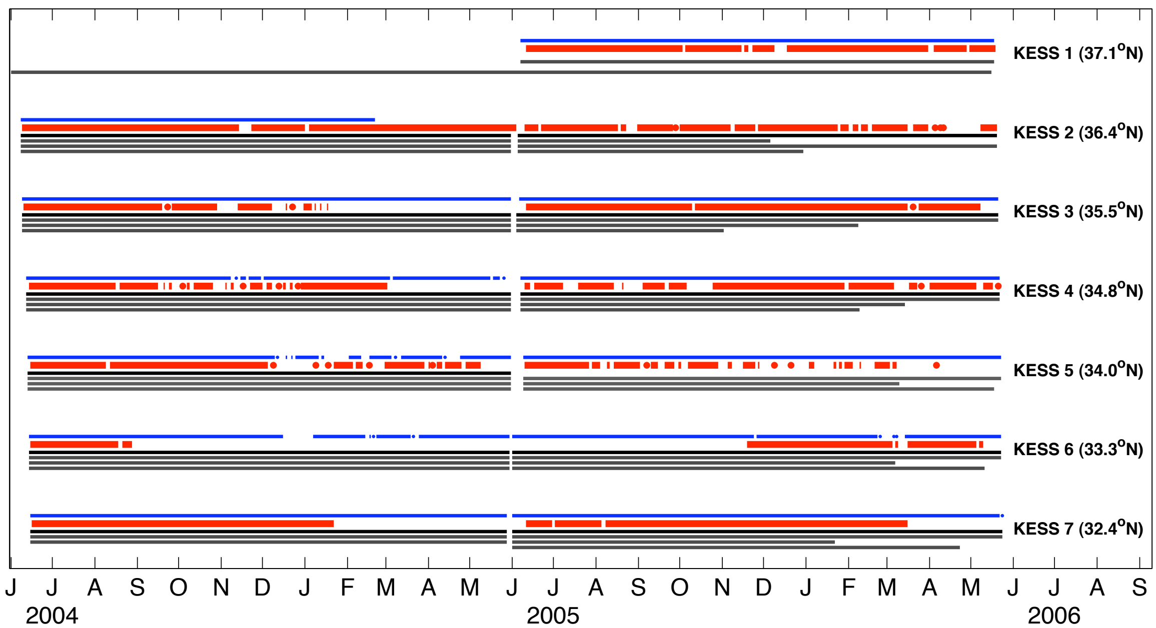

Figure 3: Data return was high from the sub-surface current measurements, but MMPs returned partial records. A line is plotted when measurements are good: ADCP (blue), MMP (red), and deep current and temperature measurements (VACM, black; RCM, gray). The turn-around cruise was in June 2005.

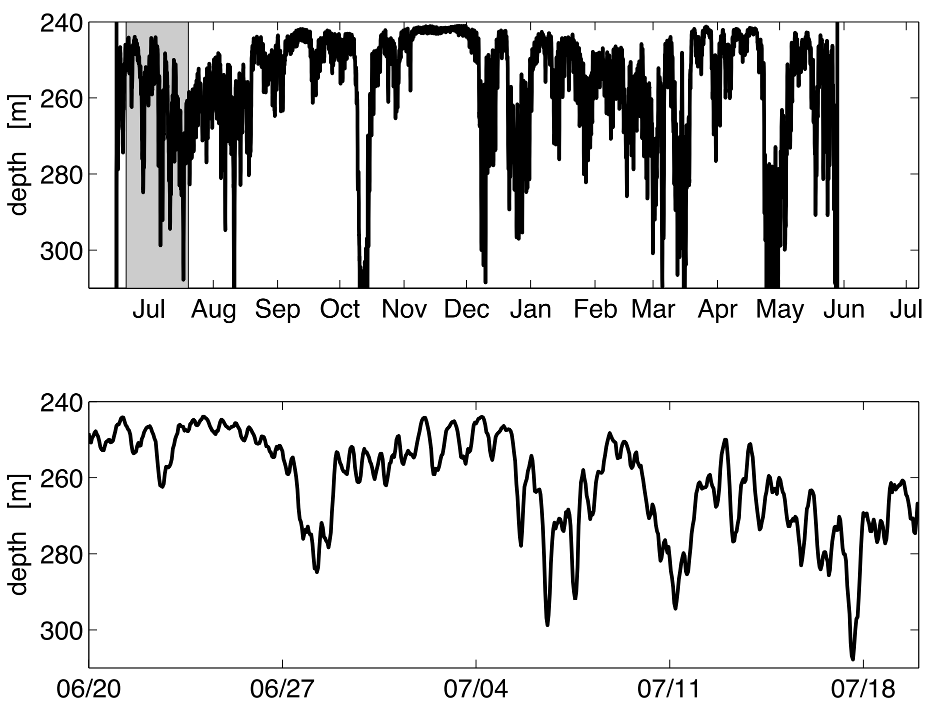

Figure 4: Depth of the ADCP at KESS 7 during the first year deployment (2004-2005). Data obtained from the PMEL TP recorder. The entire time series is shown in (a), and a close-up (indicated by the gray area) in (b). Tidal signal is evident.

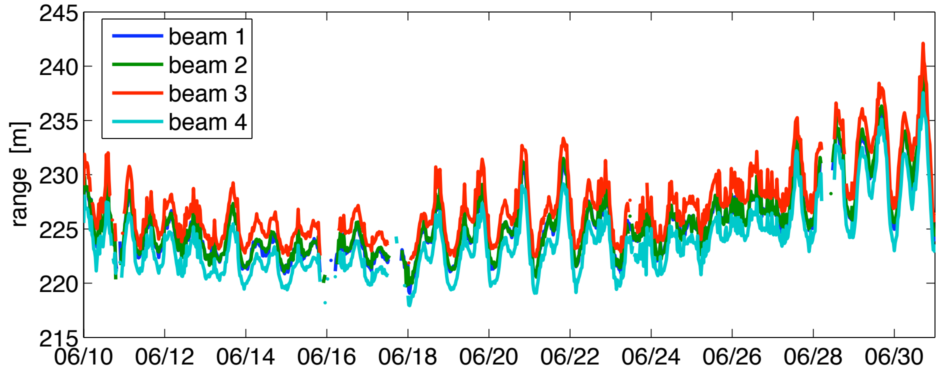

Figure 5: Ranges from the ADCP to the surface inferred from intensity profiles, from KESS 2. Each of the 4 beams is shown for a period of about 3 weeks in June 2004.

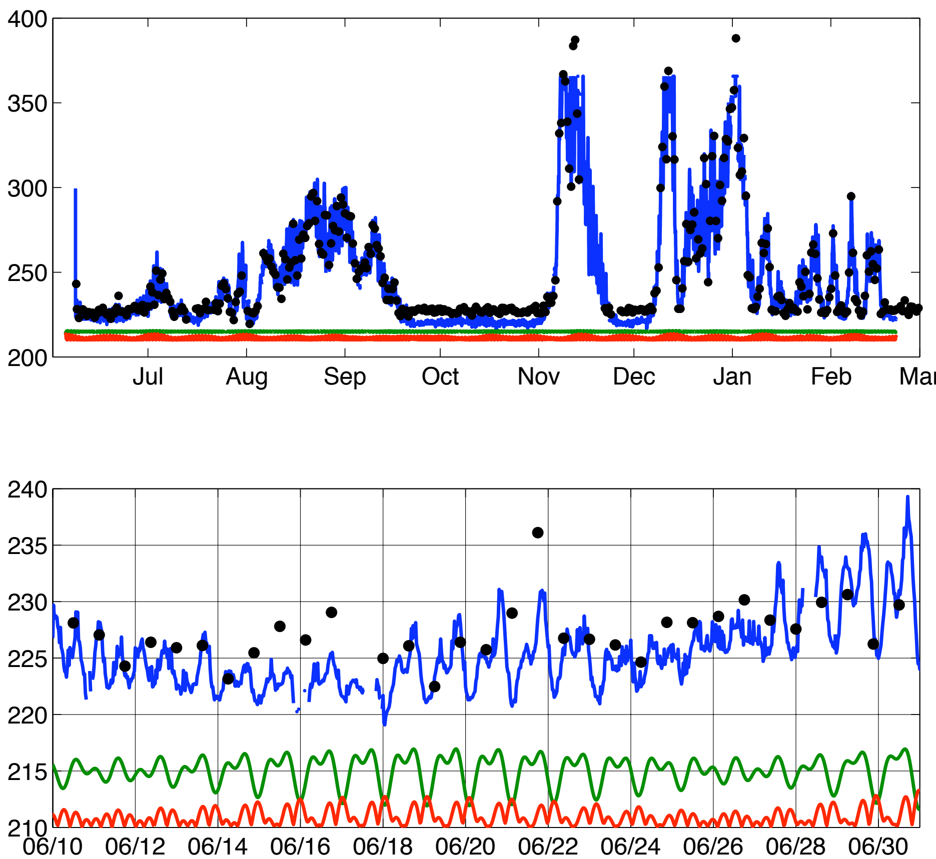

Figure 6: Distance between the surface and the ADCP, for KESS 2, during the first year (2004-2005). The best estimate from the intensity profiles is shown in blue, the minimum depth of the MMP (-20 m) is in black. The TPXO.6 barotropic tide elevation ($\times 5$ in (b)) is shown in green, and the magnitude of barotropic currents in red. (b) shows a close-up.

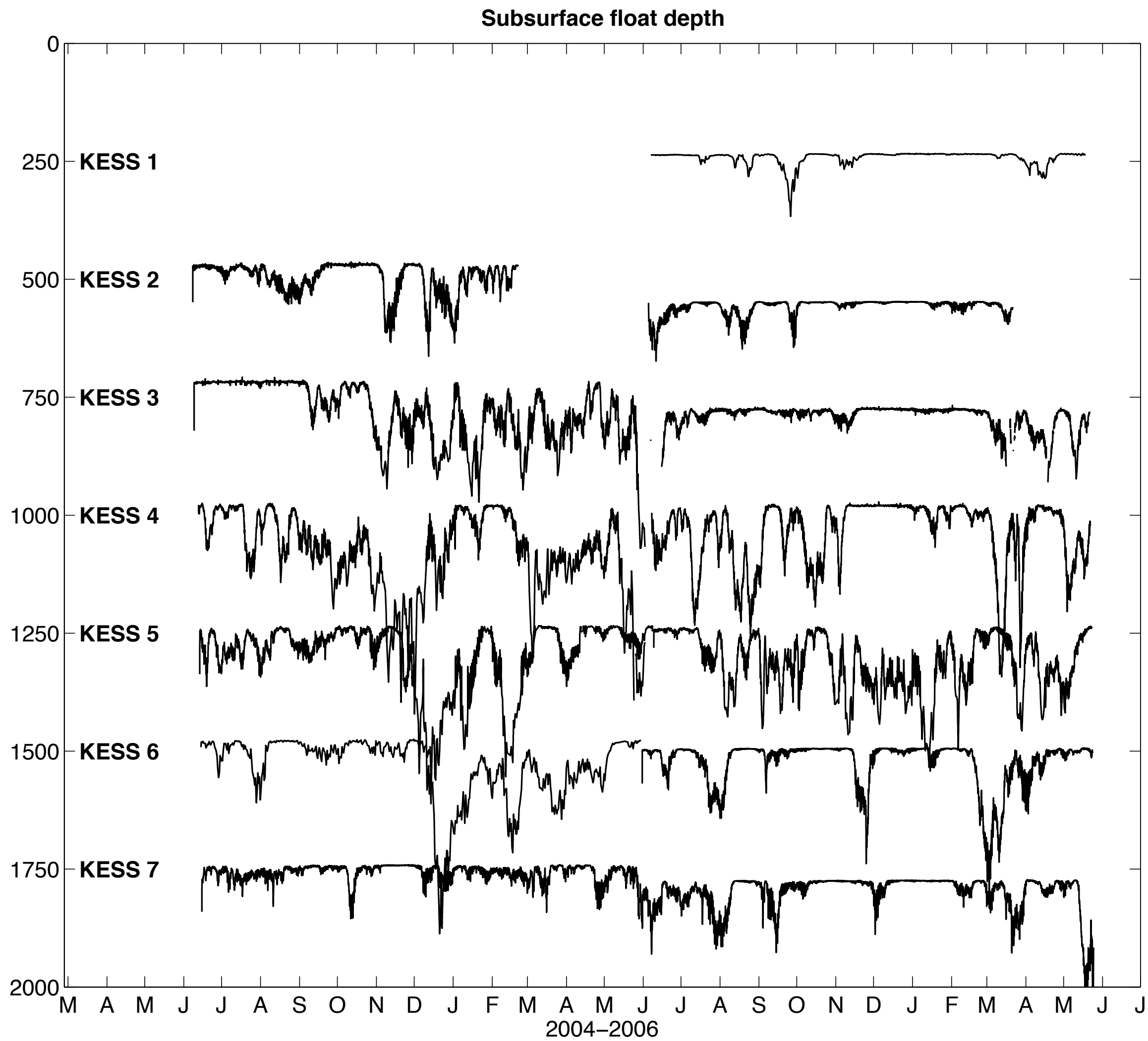

Figure 7: Time series of the depth of the ADCP at each mooring. The vertical axis is for KESS 1, and each subsequent mooring is offset by 250 m. Depths are obtained using the ADCP intensity profiles and the MMP pressure.

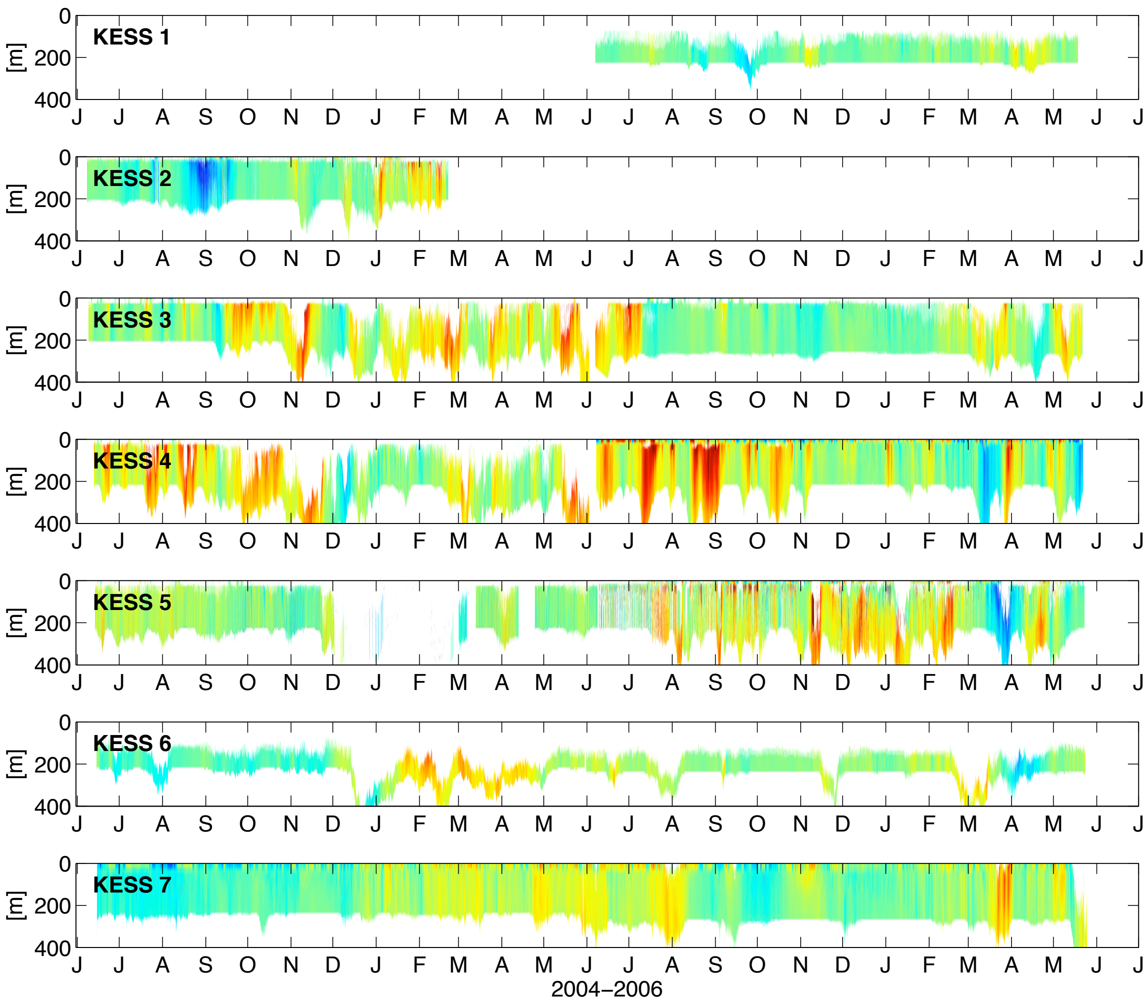

Figure 8: Depth-time maps of the ADCP east velocity, for each mooring. Colorscale is $\pm 2\mathrm{m\ s}^{-1}$.

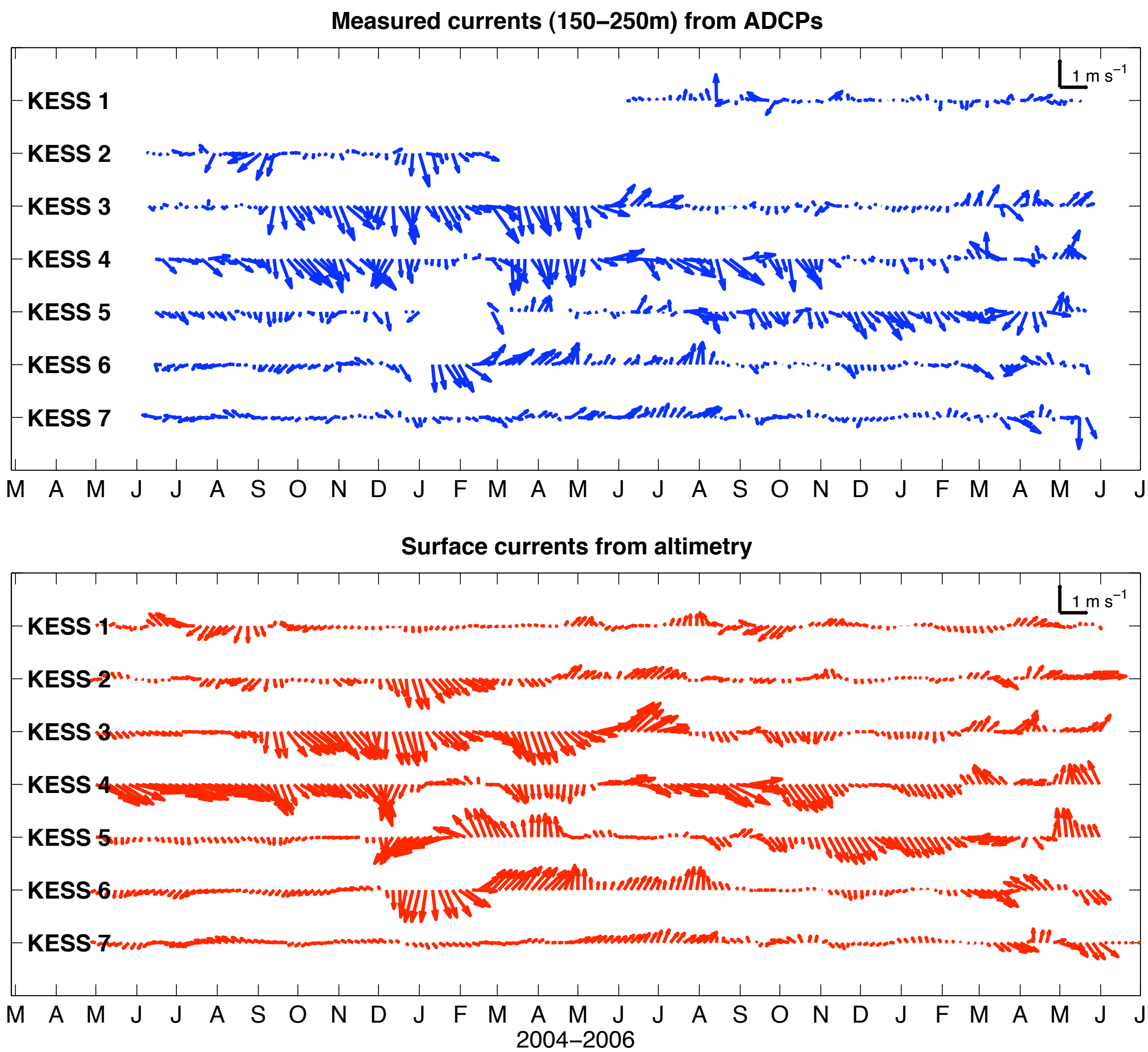

Figure 9: (a) Currents vectors (averaged from 150 to 250 m), measured from the ADCP at each mooring site. (b) Surface currents vectors inferred from the sea-surface-height maps from altimetry (AVISO).

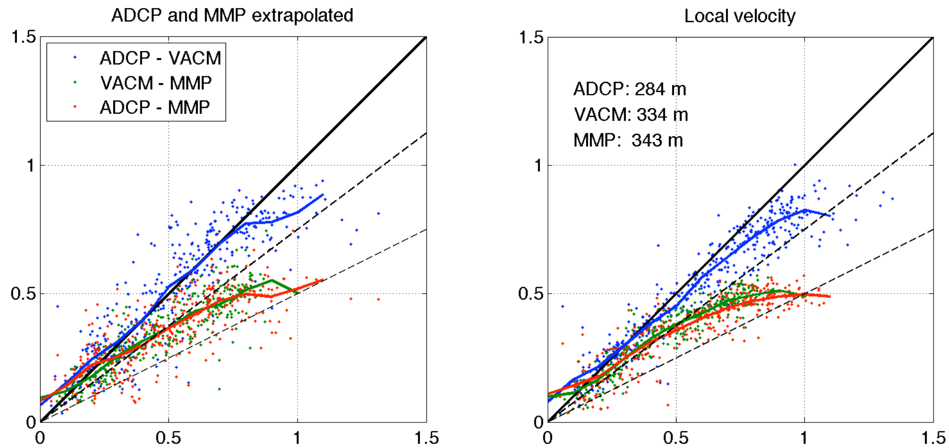

Figure 10: Comparison of the speed recorded by the ADCP, a VACM , and the MMP near 250 m during the first year at KESS-4. MMP and ADCP speeds are extrapolated to the depth of the VACM in (a) using an estimate of vertical shear, and closest data point is used in (b). Reference lines have slopes of 1, 4/3, and 2.

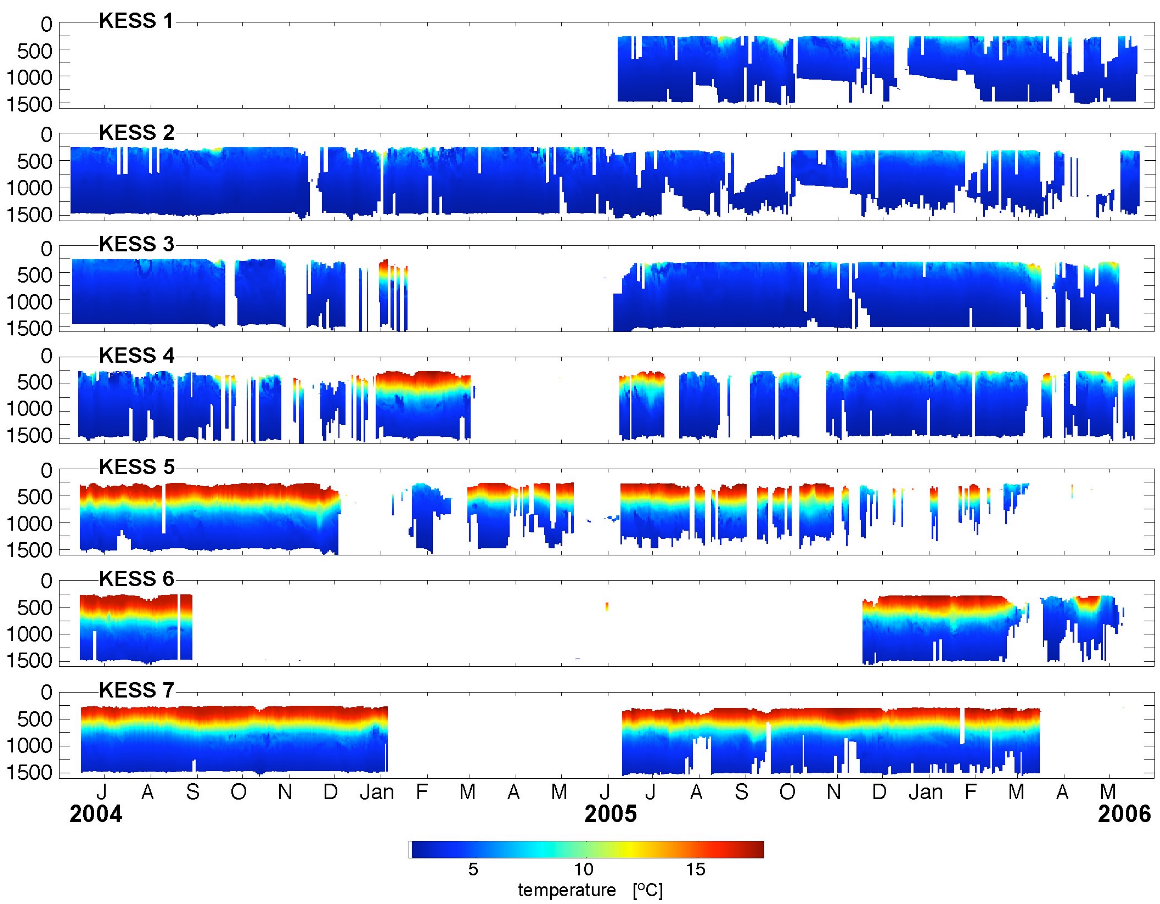

Figure 11: (a) Currents vectors (averaged from 150 to 250 m), measured from the ADCP at each mooring site. (b) Surface currents vectors inferred from the sea-surface-height maps from altimetry (AVISO).

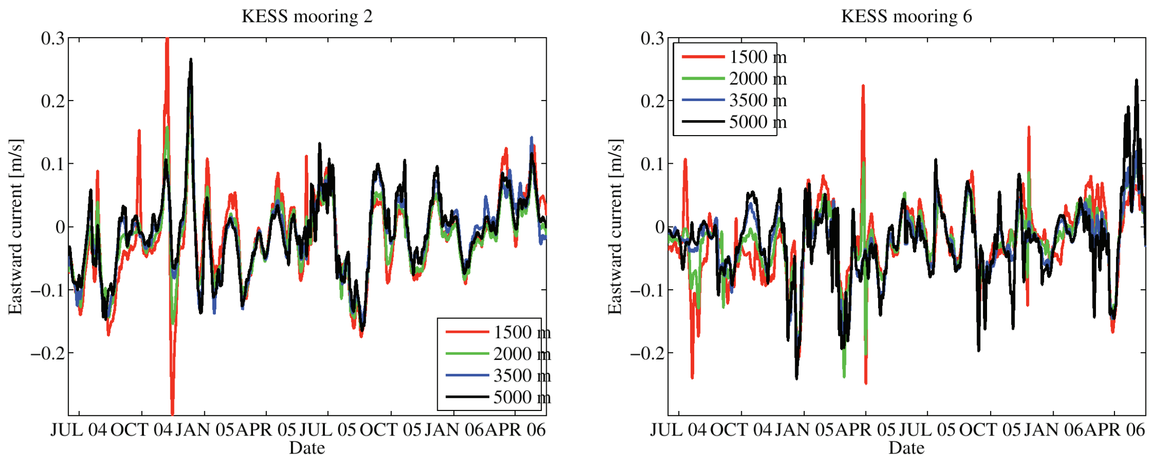

Figure 12: Deep currents at the (a) K-2 and (b) K-6 moorings. This illustrates the vertical coherence of the velocity eld, especially below the thermocline, where the variations in velocity are in phase and only weakly depth-dependent in their amplitude.

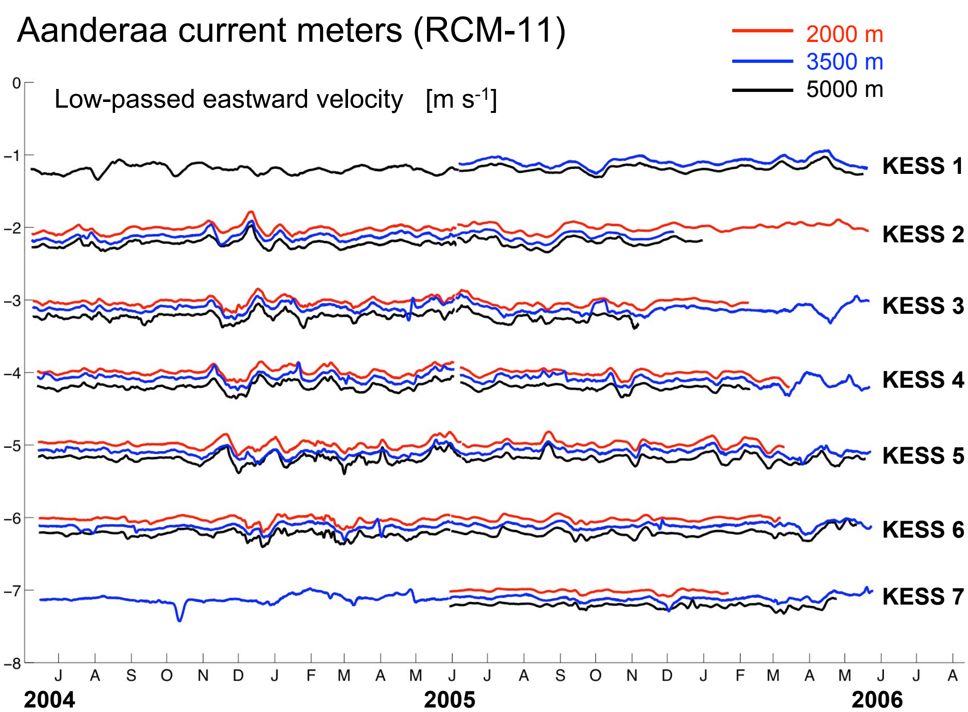

Figure 13: Low-passed east velocities from the RCMs during KESS. Moorings are offset by -1 m/s times their location number. Note the high N-S coherence.