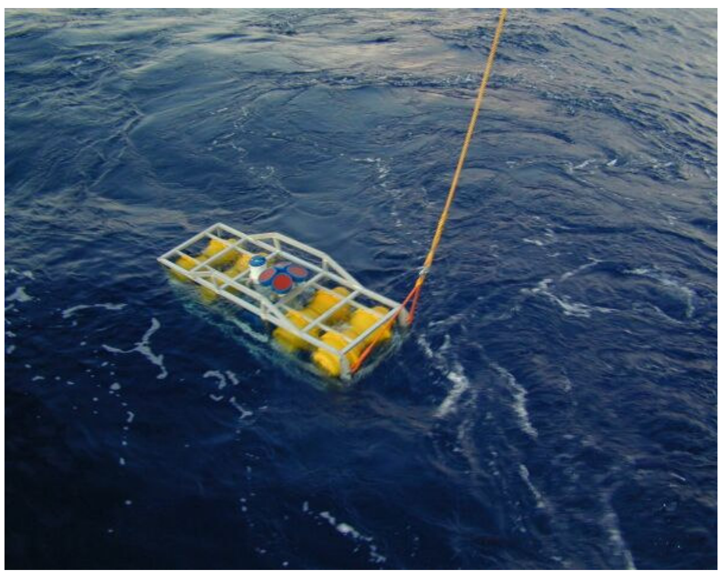
Reference:
van Haren, H., 2005. Towed ADCP- Bay of Biscay: R/V Pelagia cruise 64PE235, 20-27 April 2005, NIOZ, 15 pp.

Cruise Report

Towed ADCP

Bay of Biscay
R/V Pelagia cruise 64PE235

20-27 April 2005
Texel - Vigo



09 May 2005

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(with contributions from participants)

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0. Contents

1. Summary of R/V Pelagia cruise "Towed ADCP".

In April 2005 the R/V Pelagia (NIOZ, The Netherlands) sailed to the Bay of Biscay, whilst on transit to the Iberian Peninsula. The aim was to study internal tidal wave beams off the continental slope into the deep of the Bay of Biscay during four semidiurnal tidal periods.

The working area of "Towed ADCP" was around 47º 10′ N, 06º 10′ W (between 250-3000 m depth). Two 75 kHz acoustic Doppler current profilers (ADCP's) were mounted in a frame and towed at depths down to 800 m to monitor internal tidal beams within the ranges 200-1400 m and, in shallower water, between 30-800 m. This concept proved successful during trials above Great Meteor Seamount (Canary Basin). This time it worked as well as then, although towing at 200 m put so much strain on the cable that on-line depth read-out failed. The read-out re-established when the body was at 800 m, when the cable was towed under a less acute angle.

The cruise was successful. Weather conditions were good causing no delays. All overboard operations went very smoothly and in general the towing speeds kept the towed body within reasonable limits around the working depths. Preliminary view learned that data quality is good.

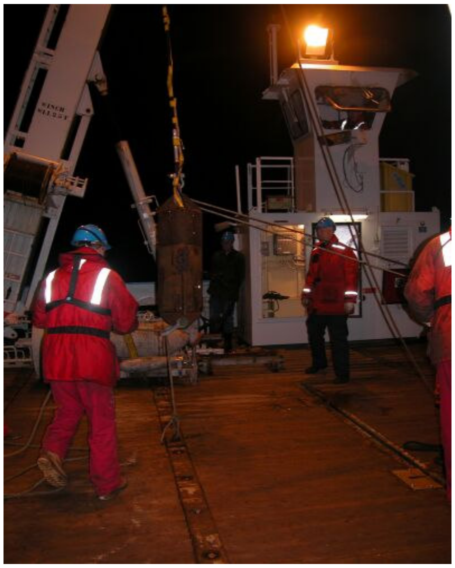

Photo: Erica Koning

2. Research aim.

Internal wave induced mixing is considered important for the maintenance of the large-scale meridian overturning circulation in the ocean and for the redistribution of nutrients and suspended matter. About half of the energy required to support this mixing is carried by tidal motions, the other half by atmospheric (wind) induced inertial motions. As waves do not mix, non-linear interaction between internal waves is assumed to transfer energy to smaller scales, eventually leading to wave breaking and mixing.

The continental slope of the Bay of Biscay is one of the most important sites for the generation of tidal waves in the ocean interior (Pingree and New, 1991). Unlike surface waves, internal waves are truly three-dimensional. They are modelled as beams of enhanced energy emanating from their dominant source near the top of the continental slope (Fig. 1). In this way they may cover large distances before causing mixing remotely from their source, for example when they ‘beach’ underwater topography. Other models predict enhanced mixing near the source of internal wave energy. Previous measurements from a single ADCP in the Bay of Biscay demonstrated enhanced internal tidal wave energy near its source (dashed box in detail plot to the right; Lam et al., 2004). However, detachment of an actual ‘beam’ away from the bottom and into the deep was not resolved.

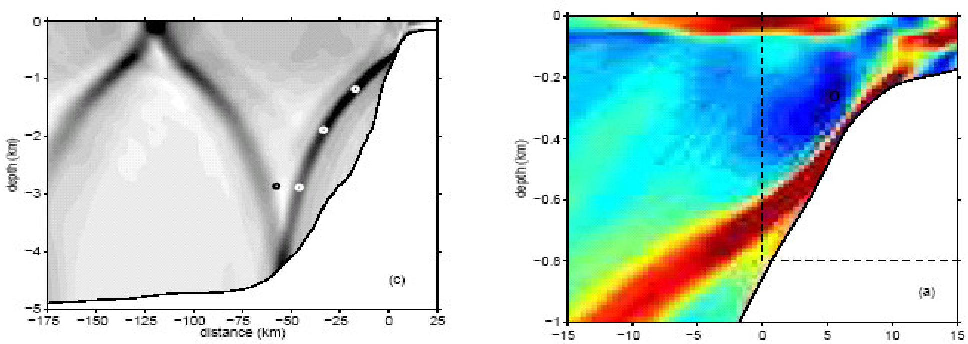

Fig. 1. Numerical model (T. Gerkema) of internal tidal beams in the Bay of Biscay: left overview; right detail.

During this R/V Pelagia cruise we attempt to monitor internal tidal wave beams using a deep-towed vehicle equipped with two 75 kHz ADCP’s (acoustic Doppler current profilers) during ~50 hours. The aim is to cover a range between 0-1400 m depth and between 300-3300 m water depth (~0-50 km horizontally in the area in Figs 2-3) to extend the previous measurements and to find the detachment from the slope, or not.

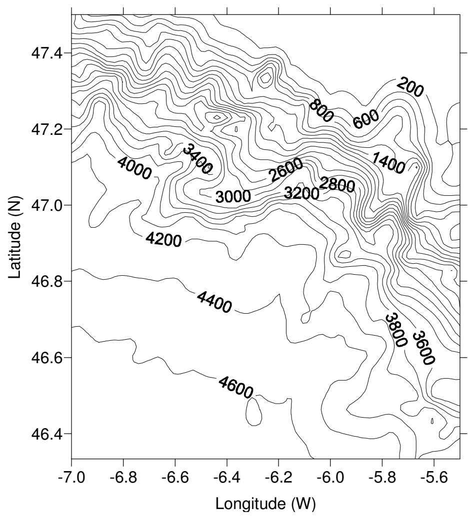

Fig. 2. Topography of the Bay of Biscay research area (M. Hiehle).

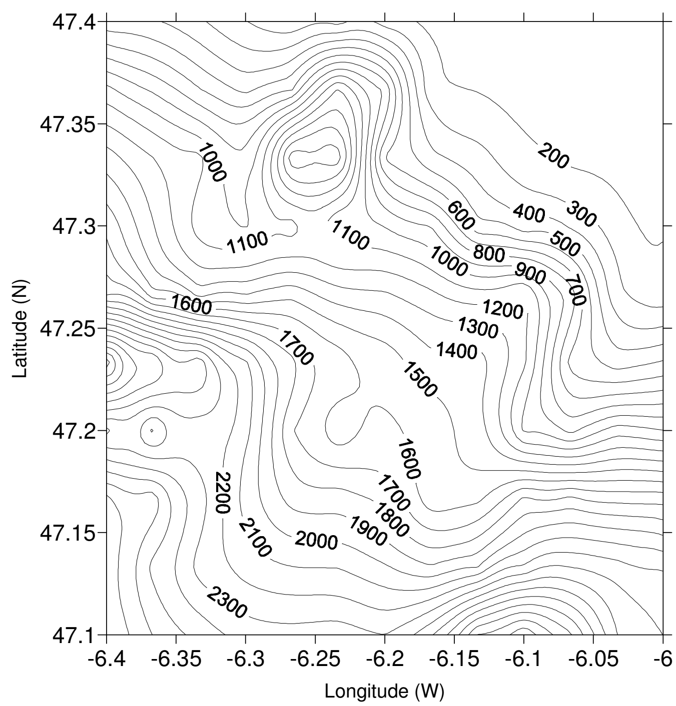

Fig. 3. Detail of Fig. 2 (M. Hiehle) Intended track runs from upper right to ~ lower left.

3. Participants.

Institute	*Name*
FYS	Hans van Haren (PI)
FYS	Leo Maas
FYS/DMG	Margriet Hiehle
MTE	Martin Laan
MTM	Yvo Witte
MTM	Leon Wuis
IMAU Utrecht	Erik van Sebille
IMAU Utrecht	Selma Huisman
IMAU Utrecht/FYS	Eline Verwer
Also on board on transit: the MOVE! team and Hermes PI:	
MCG	Henko de Stigter
MCG	Eric Epping
MCG	Erica Koning
MTE	Dirk-Jurjen Buijsman
MTI	Johan van Heerwaarden
FM	Pieter van Kralingen

NIOZ departments

FYS	physical oceanography
MTE	marine technology electronics
MTI	marine technology instrumentation
MTM	marine technology mechanics
DMG	data management group
MCG	marine chemistry and geology
FM	facility management

Photo: Erica Koning

4. Data acquisition and instrumentation.

We attempt to monitor internal tidal wave beams above steep topography using a deep-towed vehicle equipped with two 75 kHz RDI LongRanger ADCP's (one up-, another down-looking). The instruments are programmed to cover 600 m vertical range each and sample 7 pings in 20 s in 10 m vertical bins, using a transmission length of 9.85 m. The instruments ping asynchronously to avoid cross-talk. The neutrally buoyant vehicle is attached to a 1500 kg pistoncorer weight and an additional 1000 kg weight with SeaBird CTD pressure sensor that are towed using a Kevlar line + electric cable. The ADCP's store data internally, but pressure information is available on-line through the electric cable. Trials in the Canary Basin in 2004 learned that a towing speed of ~3 knots is acceptable, with 1350 m Kevlar line paid-out when the towed body is at 800 m. In this configuration a transect of sides ~12 km can be sailed 5 times within a semidiurnal tidal period. Five data points resolve the tidal wave sufficiently when modelled by a single sinusoid. As a result, four such transects are sailed, partially overlapping.

In addition to the towed ADCP's the ship's 75 kHz ADCP (VMADCP) is also used over a range of ~30-500 m. The VMADCP sampled each ping every 3.81 s.

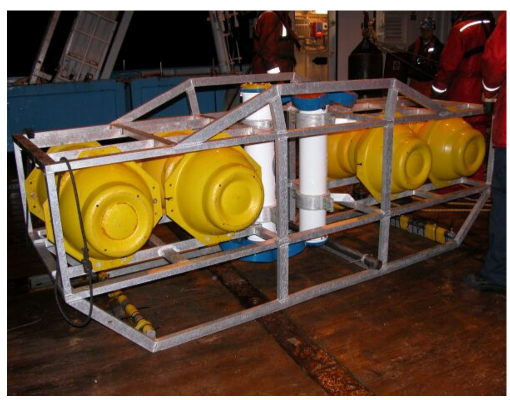

Photo (Erica Koning): Deep-towed body with up- and downlooking ADCP.

5. Daily summaries of cruise Towed ADCP.

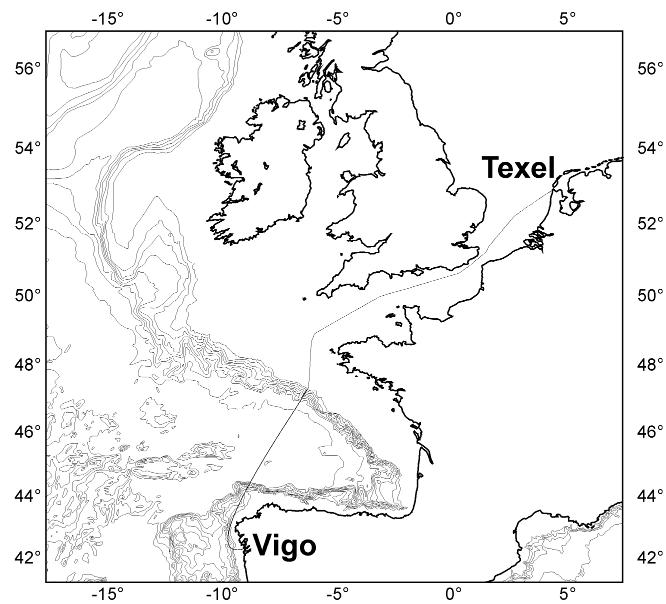

Fig. 4. Towed ADCP cruise track and activity locations (M. Hiehle)

Wednesday 20 April

13.15 UTC departure from Texel, The Netherlands. Good weather conditions.

Saturday 23 April

S4-7. 02 UTC. Arrival in working area, above the continental slope to the southwest of Brest, France. First tests with winch and ADCP's are successful. Some problems with depth reading of towed body are rapidly solved. 03:50 UTC start of 50 h towed-body tracks in direction 212/32°. Four tracks of ~6 miles long are sampled five times at a speed of 3 knots. During the first track the towed body is held at 200 m depth, during all others at 800 m.

Sunday 24 April

S3. Continue towing.

Monday 25 April

W3-6. 06 UTC. End of towing. Final long track is sailed for bottom topography including a calibration of sensors. 18 UTC en route to Vigo, Spain.

Wednesday 27 April

W5-calm. 14 UTC. Arrival in Vigo Bay. Five passengers disembark, three embark. End of cruise Towed ADCP.

6. Scientific summary and preliminary results

Just prior to the towed ADCP transects a few trials were performed with the system. All tests were successful, except for some noise in the depth (pressure sensor) read-out of the CTD mounted in the first weight. This was a known problem from the trial cruise in the Canary Basin in October 2004, so it was solved quickly by diverting the electric cable far from the winch's power unit. During the Canary Basin cruise the entire rather complex procedure of sailing a deep-towed vehicle was well documented (van Sebille, Loeve and Huisman, 2004). This procedure was strictly followed here, including the set-up of transects and the way to make U-turns (Fig. 5).

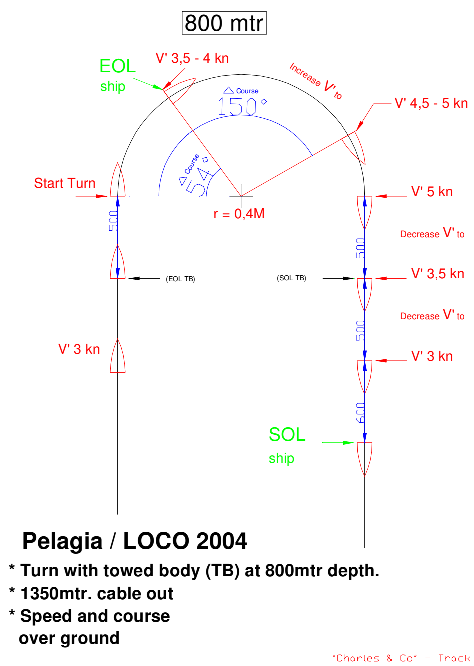

Fig. 5. Diagram of U-turn with towed body at 800 m depth (Charles & co.)

The sequence of the deep towed-ADCP was performed for a consecutive period of 52 hours (~4 semidiurnal tidal periods) above the continental slope in the Bay of Biscay (Fig. 6). Tow speed was 3±0.4 knots and transects of ~11 km length were sampled 5 times each. The speed variation sometimes meant towed body depth variation of ±20 m, but other times depth variations were caused by local current variation.

The towing depths were 200 m (one transect; slightly longer: 12.5 km) and 800 m (three transects). Due to the steepness of the slope, the '200 m' transect and the first '800 m' transect overlapped by about 7 km. The '800 m' transects overlapped 900 m. The direction of all transects was 212°TN (return: 32°TN), with starting point of the ‘200 m’ transect at 47°17.689´N, 06°05.956´W (water depth 250 m). Final water depth was 3100 m. During the entire measurement period weather conditions were reasonable-good and towing was still possible during a spell of Bf7.

Like in 2004, the cable vibrated so much when the towed body was at 200 m that no online read-out of depth was available. After lowering the towed body to 800 m the line was under a less acute angle, vibration decreased and online read-out was available again, although with a limited but regular amount of errors.

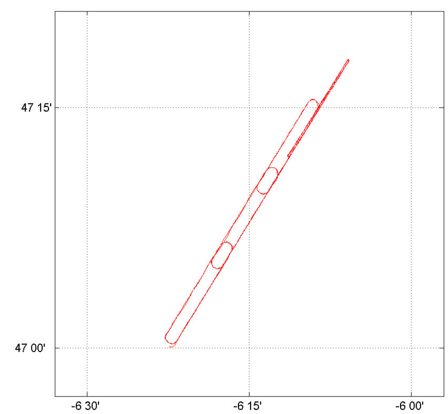

Fig. 6 Towed track (Erik van Sebille/ Selma Huisman) The thin stadium is the ‘200 m’ track, the others are ‘800 m’ tracks.

Preliminary inspection of the data learned that the instruments worked well. During the towing with the frame at a depth of 200 m the online CTD readings were occasionally hampered, but these data are not of primary use during the analysis. With the VMADCP reaching to about 500 m depth and the towed body ADCP’s ranging at least 550 m, a total depth is reached of 1350 m (body at 800 m), with several ranges of overlap. Data quality is good, and no gap occurred in the VMADCP series (as was observed in 2004). However, the file structure of the VMADCP is still a mystery, and no further analysis could be performed on board. Depth variations were generally within reasonable limits of ±25 m. Instrumental tilt was never more than 5° ensuring the good data quality and sufficient depth range.

Already in the raw data a banding of enhanced and weakened currents can be seen (Fig. 7), which however varies in magnitude, indeed more or less with the tidal cycle.

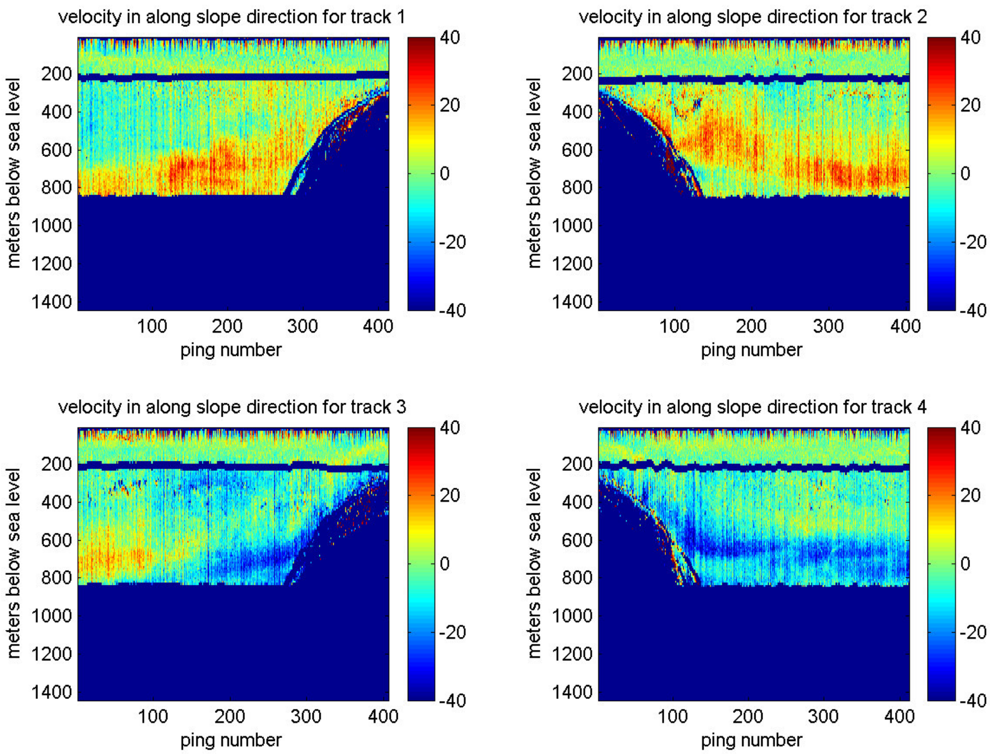

Fig. 7 Raw along slope data of first four tracks with towed body at 200 m (Erik van Sebille/ Selma Huisman).

Preliminary analysis of the raw data, in which towed body motions are corrected, but in which water motions are computed relative to a particular depth level as GPS data of ship's speed are not yet incorporated, shows a clear banding of semidiurnal tidal amplitude (Fig. 8) and phase (Fig. 9). Remarkable are the relatively weak amplitudes near the slope itself, but an otherwise recognizable weak amplitude zone around 800 m further offshore. The varying amplitude in the direction of a "beam" is also new. This suggests a grouping of tidal energy within a beam, possibly due to variations in stratification, and, thus, generation. A rough estimate suggests a beam slope of 3%, which corresponds to a semidiurnal tidal beam slope at this latitude if N = 40 cpd, which is more or less the observed value around 800 m (to within 20% variation). Rapid phase changes are observed in the beam in a direction ~perpendicular to the beam slope, as before. Less clear is the expected detachment of the beam from the slope.

However, the sometimes step-like transitions across different tracks, in amplitude and/or phase, indicate that the analysis is not yet perfect. Also, longer series in overlapping sections demonstrate relatively large contamination of higher tidal harmonics, causing asymmetric tidal waves, even with longer periods than semidiurnal. This requires further attention.

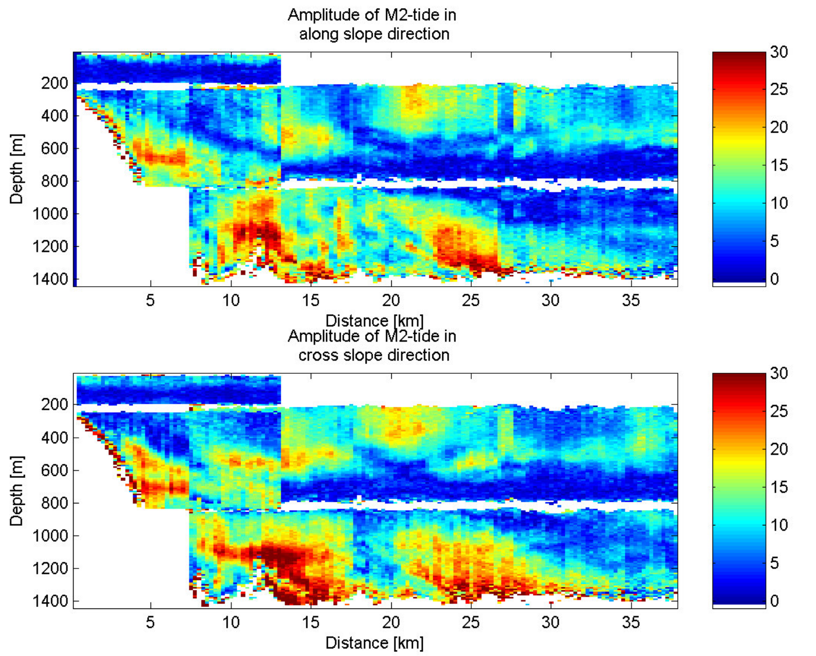

Fig. 8 Preliminary analysis of tidal amplitude in cm/s, with down- and upward sloping high eamplitude bands (Erik van Sebille/ Selma Huisman).

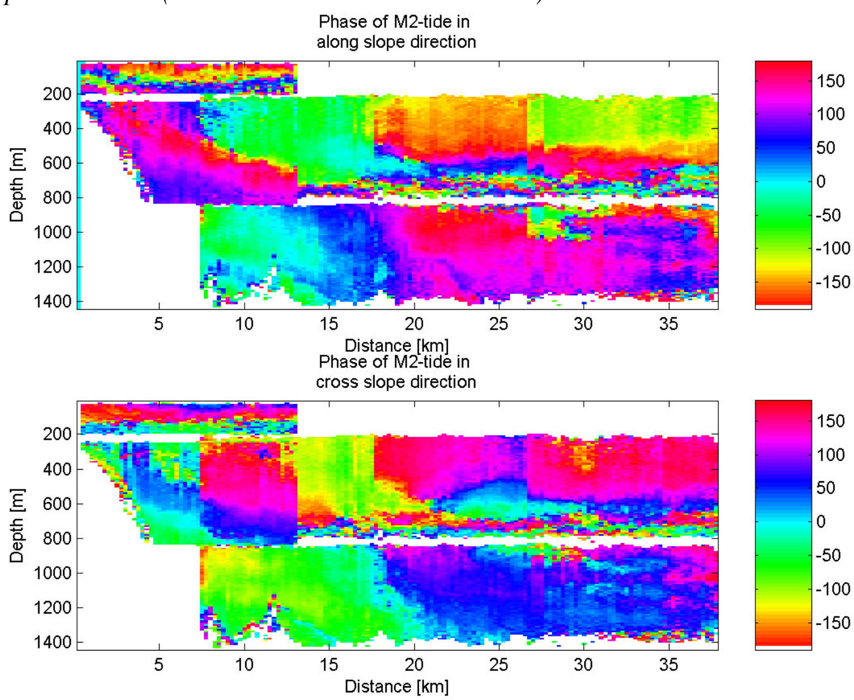

Fig. 9 Preliminary analysis of tidal phase in degrees (Erik van Sebille/ Selma Huisman).

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7. Achnowledgments

On behalf of the participants, I would like to thank captain John Ellen and the crew of R.V. Pelagia for the very pleasant cooperation.

May 2005,

Hans van Haren

Photo: Erica Koning

APPENDIX A Cruise summary of events of Towed ADCP* (M. Hiehle*)

Event	Datum/ Tijd		Lat	Lon	Diepte
Begin	apr 23	2005 03:47:22	47.19785	-6.19455	1320
SOL 1	apr 23	2005 03:56:25	47.20325	-6.18768	1254
EOL 1	apr 23	2005 06:13:45	47.29918	-6.09848	228
SOL 2	apr 23	2005 06:21:40	47.29482	-6.09927	241
EOL 2	apr 23	2005 08:35:31	47.199	-6.18808	1280
SOL 3	apr 23	2005 08:43:06	47.20312	-6.18703	1243
EOL 3	apr 23	2005 10:57:59	47.29897	-6.09818	221
SOL 4	apr 23	2005 11:06:42	47.29507	-6.09993	243
EOL 4	apr 23	2005 13:23:33	47.19892	-6.18815	1280
SOL 5	apr 23	2005 13:29:55	47.20308	-6.18678	1243
EOL5	apr 23	2005 15:47:27	47.29918	-6.09828	253
SOL 6	apr 23	2005 15:56:28	47.29483	-6.09942	274
EOL 6	apr 23	2005 16:38:20	47.26555	-6.12667	1281
SOL 7	apr 23	2005 17:20:06	47.23555	-6.15437	1267
EOL 7	apr 23	2005 19:09:40	47.15945	-6.22788	1841
SOL 8	apr 23	2005 19:40:03	47.18243	-6.22525	1767
EOL 8	apr 23	2005 21:54:06	47.25843	-6.1513	1132
SOL 9	apr 23	2005 22:18:36	47.2355	-6.1542	1263
EOL 9	apr 24	2005 00:11:06	47.1603	-6.228	1841
SOL 10	apr 24	2005 00:38:02	47.18242	-6.22565	1776
EOL 10	apr 24	2005 02:27:07	47.2582	-6.15112	1144
EOL 11	apr 24	2005 04:44:07	47.1655	-6.21765	1649
SOL 12	apr 24	2005 04:44:09	47.1655	-6.21765	1649
EOL 12	apr 24	2005 06:53:56	47.08262	-6.2997	2287
SOL 13	apr 24	2005 07:21:02	47.10387	-6.29482	2169
EOL 13	apr 24	2005 09:42:09	47.18762	-6.21558	1557
SOL 14	apr 24	2005 10:08:16	47.1654	-6.21828	1654
EOL 14	apr 24	2005 12:05:03	47.08268	-6.29883	2282
SOL 15	apr 24	2005 12:32:22	47.10487	-6.29577	2154
EOL 15	apr 24	2005 14:35:26	47.1875	-6.21443	1562
SOL 16	apr 24	2005 15:04:13	47.16545	-6.21817	1659
EOL 16	apr 24	2005 17:07:10	47.08748	-6.28837	2470
SOL 17	apr 24	2005 17:07:13	47.08748	-6.28837	2470
EOL 17	apr 24	2005 19:20:49	47.00455	-6.36927	2974
SOL 18	apr 24	2005 19:49:14	47.02692	-6.3663	2676
EOL 18	apr 24	2005 22:07:38	47.1100	-6.2862	2444
SOL 19	apr 24	2005 22:31:55	47.08758	-6.28895	2450
EOL 19	apr 25	2005 00:28:34	47.00432	-6.36923	2968
SOL 20	apr 25	2005 00:55:33	47.02707	-6.36683	2676
EOL 20	apr 25	2005 02:59:06	47.11005	-6.28633	2224
SOL 21	apr 25	2005 03:30:43	47.0875	-6.28853	2456
EOL 21	apr 25	2005 05:48:42	47.00313	-6.36513	3145