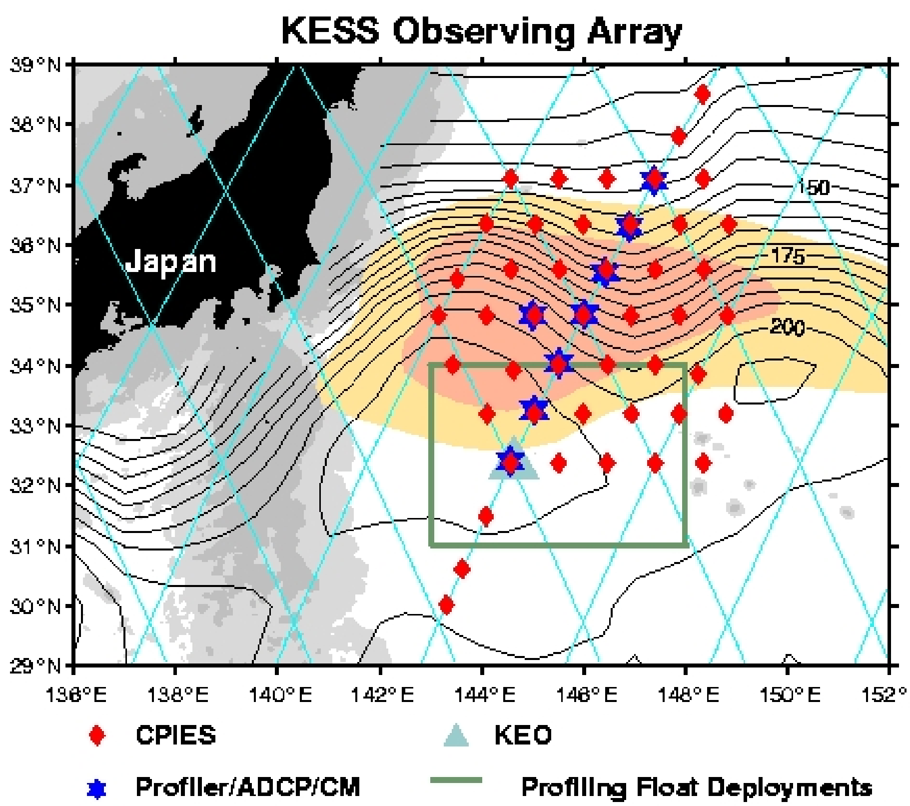
GRADUATE SCHOOL OF OCEANOGRAPHY
UNIVERSITY OF RHODE ISLAND
NARRAGANSETT, RHODE ISLAND

Inverted Echo Sounder Data Report

Kuroshio Extension System Study (KESS)
April 2004 to July 2006

GSO Technical Report 2008-02



by
Maureen Kennelly
Kathleen Donohue
Andrew Greene
Karen L. Tracey
and
D. Randolph Watts

July 2008

ABSTRACT

As part of the Kuroshio Extension System Study (KESS), observations were made during April 2004 to July 2006 to identify and quantify the dynamic and thermodynamic processes governing the variability of and the interaction between the Kuroshio Extension and the recirculation gyre to the south. KESS is a collaborative project between U.S. and Japanese scientists.

For KESS, a moored array was designed to measure the time-varying density and velocity fields with the 4-D mesoscale resolution required to determine dynamical balances and cross-frontal exchanges of heat, salt, momentum, and potential vorticity. This array was centered on the first quasi-stationary meander trough east of Japan and in the region of highest eddy kinetic energy. The array comprised inverted echo sounders equipped with bottom pressure gauges and current meters (CPIES) and McLane moored profilers (MMPs) equipped with upward looking acoustic Doppler current profilers (ADCPs) and deep current meters (CMs). CTD/shipboard acoustic Doppler current profiler (SADCP) surveys measured the broad-scale density and velocity structure. Argo profiling floats deployed within the recirculation gyre monitored the temporal evolution of the temperature and salinity in the near-surface mixed layer, the subtropical mode water, and the intermediate waters. Surface flux measurements from the Kuroshio Extension Observatory (KEO) buoy contributed to climate studies of the role of the Kuroshio jet and its recirculation gyre. To help understand the connection of the Kuroshio Extension and the recirculation gyre to the atmosphere and climate, surface air-sea flux measurements were conducted (atmospheric soundings).

In this report, the CPIES data collected by URI researchers during the field experiment are presented. The collection, processing and calibration of the CPIES are documented. Time series plots of travel time, bottom pressure, temperature and currents are presented. Basic statistics of the hourly data are tabulated.

Contents

List of Figures

List of Tables

List of Acronyms

ADCP	Acoustic Doppler current profiler
BA	Basin average
CM	Current meter
CPIES	IES with optional current meter and pressure sensor
CTD	Conductivity, Temperature, Depth
DCS	Doppler current sensor
IES	Inverted echo sounder
GEM	Gravest Empirical Mode
GSO	Graduate School of Oceanography
KEO	Kuroshio Extension Observatory
KESS	Kuroshio Extension System Study
MMP	McLane Moored profiler
PIES	IES with optional pressure sensor
RESPO	Response analysis of tides
SADCP	Shipboard acoustic Doppler current profiler
SN	Serial number
URI	University of Rhode Island
WHOI	Woods Hole Oceanographic Institution

1 Setting and Experiment Design

1.1 Introduction

This report focuses on data collected from an array of inverted echo sounders equipped with bottom pressure gauges and current meters (CPIES) at 46 sites (Figure 1) in the Kuroshio Extension east of Japan on a grid spanning from the southern recirculation region to the mixed water regime and coordinated with Jason satellite altimeter ground tracks from April 2004 to July 2006. The CPIES were moored in water depths ranging from 5300 m on the western side of the array to 6300 m in the east. Calibration CTDs were taken at each site. The measurements presented here were made as part of the collaborative Kuroshio Extension System Study (KESS) under the support of the National Science Foundation, Grant No. OCE02-21008. KESS collaborators included investigators from the NOAA Pacific Marine Environmental Laboratory, the University of Hawaii, Woods Hole Oceanographic Institution, Scripps Institution of Oceanography and Hokkaido University.

Further details of the GSO/URI component of KESS may be found at http://www.po.gso.uri.edu/dynamics/KESS. In this report the collection, processing, and calibration of the CPIES data are documented. Measurements made by KESS collaborators are discussed elsewhere (see http://uskess.org) and included McLane moored profilers (MMPs) equipped with upward-looking acoustic Doppler current profilers (ADCPs) and deep current meters (CMs), CTD/shipboard acoustic Doppler current profiler (SADCP) surveys, Argo profiling floats, surface drifters and a surface meteorological buoy.

1.2 CPIES/PIES Description

In its simplest mooring configuration, an inverted echo sounder (IES) is housed in a single glass sphere connected to an anchor by a 1 m length of cable. When a Paroscientific pressure sensor is added to the glass sphere (PIES), the package requires an anchor stand to prevent movement affecting the pressure measurement. When an Aanderaa Doppler current sensor (DCS) is incorporated into the package (CPIES), a second glass floation sphere is needed to keep the mooring cable upright.

For the KESS field work, GSO/URI Model 6.1E2 CPIES were used. All CPIES moorings consisted of two 17 inch glass spheres connected by cable, an Aanderaa DCS located 50 m above the IES and a 150 lb anchor stand (Figure 2). All instruments were equipped with Paroscientific bottom pressure sensors (full-scale range 10,000 psi, approximately 6800 dbar) in the lower glass sphere located 1 m above the ocean floor.

Measurements of vertical acoustic travel time (tau, τ), pressure and temperature were made every ten minutes throughout the field program. DCS u, v and temperature measurements were made every 20 minutes with the exception of H3 (SN 112), S1 (SN 101) and S2 (SN 102) which sampled every 10 minutes. At the deployment depths of the KESS array (5300-6300 m), travel times varied between 7 and 8.5 s. The KESS instruments included a new acoustic telemetry capability to check data quality immediately after launch and to obtain transmitted daily processed data. Acoustic communication with the CPIES was through a hull-mounted 12 kHz transducer.

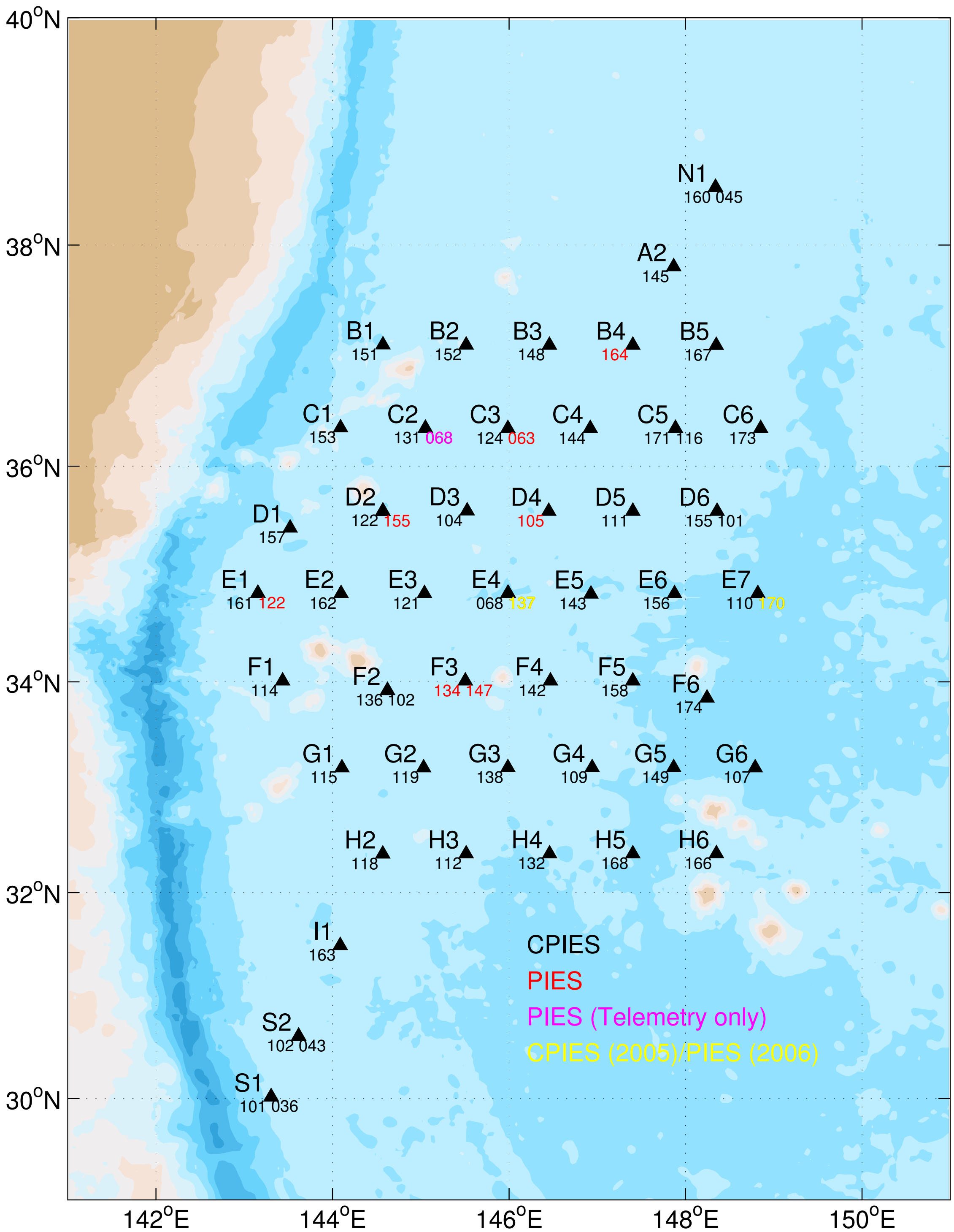


Figure 1: KESS array superimposed on Smith and Sandwell bathymetry countoured every 1000 m. Site reference in large bold font in the upper left hand corner. Color-coded IES serial numbers under the triangles: black for CPIES sites, red for PIES sites, magenta specifying sites where only telemetry was taken, and yellow for sites where the same instrument was a CPIES for 2004, but a PIES in 2005.

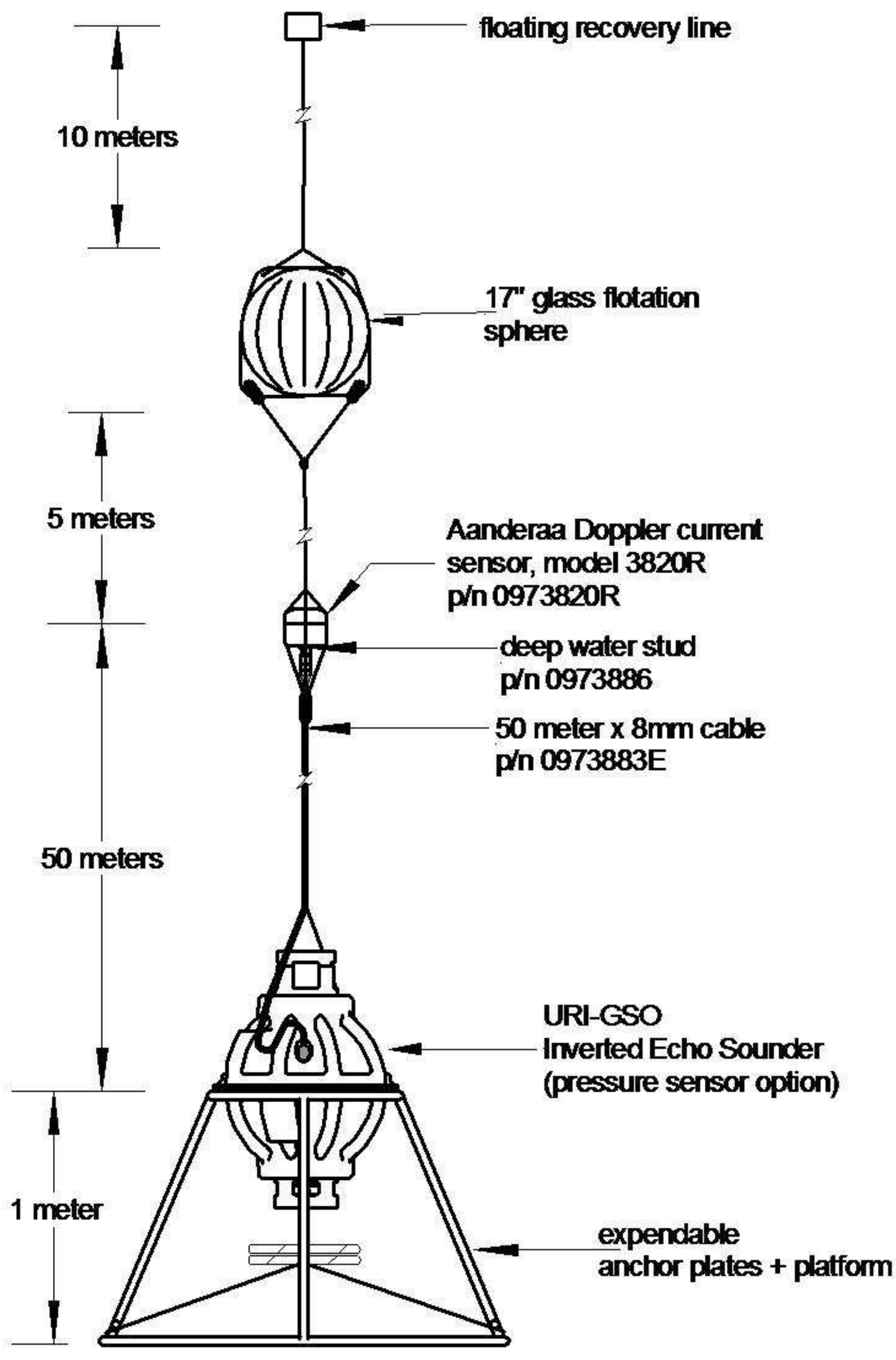


Figure 2: CPIES Schematic.

1.3 Data Recovery

The KESS IES fieldwork consisted of three cruises: deployment, telemetry and recovery (Table 1).

Cruise Number	Cruise Dates	Cruise Description
Thompson TN168-1	15 April - 1 June 2004	Deploy CPIES
Revelle ZHNG08RR	17 June - 17 July 2005	CPIES data telemetry
Melville Magellan 4	1 June - 5 July 2006	Recover CPIES

Table 1: IES Cruises.

An array of 50 CPIES sites had been proposed and an additional three sites were anticipated. However, instrument failures during the deployment cruise reduced the array to the 46 sites shown in Figure 1. Deployments at sites designated as H1 and I2 (not shown in Figure 1) had been attempted, but were unsuccessful. Sites A1, D7, E8 and F7 were never occupied. As a cost-saving measure, sites B4, D4 and F3 were planned to be PIES sites rather than CPIES. At these three sites we proposed to use the bottom CMs on the MMPs to obtain current data.

To address instrument problems discovered during the telemetry cruise in 2005, many IESs were recovered and replaced with different instruments. At 6 sites (C2, C3, D2, E1, E4 and E7), instruments were converted to PIES during the telemetry cruise by removing the Aanderaa DCS. CPIES SN 68 was deployed at Site E4 in 2005 but was recovered after only two weeks because the DCS failed. That instrument was subsequently converted to a PIES and redeployed at Site C2. In some cases, to ensure data coverage, duplicate instruments were placed at the same site.

The deployment locations of the CPIES/PIES and the periods of coverage for τ, pressure, and u, v for which good data are available are listed in Table 2. Sites occupied by PIES, rather than CPIES are denoted by an asterisk. If two instruments were recovered at the same site in the same year, an “a” was appended to the site designation of the second instrument’s data files (C3a, C5a, E4a, E7a, F3a, and N1a).

Table 2

Site	SN	τ Start	τ End	P Start	P End	u, v Start	u, v End	Launch	Recovery	Lat	Lon	Depth
A2	145	5/27/2004	6/20/2006	5/28/2004	6/20/2006	5/27/2004	6/20/2006	5/27/2004	6/20/2006	37 48.51	147 51.93	5689
B1	151	5/18/2004	4/4/2006	5/18/2004	4/4/2006	5/18/2004	4/5/2006	5/18/2004	6/18/2006	37 06.31	144 34.26	5568
B2	152	5/17/2004	3/10/2006	5/18/2004	3/10/2006	5/17/2004	12/6/2005	5/17/2004	6/18/2006	37 06.25	145 30.86	5425
B3	148	5/17/2004	6/20/2006	5/18/2004	6/20/2006	5/17/2004	9/14/2005	5/17/2004	6/20/2006	37 06.17	146 27.53	5596
B4*	164	5/17/2004	12/2/2005	5/18/2004	12/2/2005	N/A	N/A	5/17/2004	6/20/2006	37 06.15	147 24.22	5644
B5	167	5/26/2004	12/6/2005	5/26/2004	12/6/2005	5/25/2004	12/7/2005	5/25/2004	6/22/2006	37 06.08	148 20.91	5722
C1	153	5/18/2004	12/10/2005	5/19/2004	12/10/2005	5/18/2004	11/8/2005	5/18/2004	6/18/2006	36 21.11	144 05.44	5745
C2	131	5/12/2004	3/4/2005	5/13/2004	3/4/2005	5/12/2004	3/5/2005	5/12/2004	7/14/2005	36 20.89	145 03.16	5695
C2*	68	7/14/2005	6/19/2006	7/14/2005	6/19/2006	N/A	N/A	7/14/2005	lost	36 20.89	145 03.19	5761
C3	124	5/12/2004	6/19/2006	5/13/2004	6/19/2006	5/12/2004	5/21/2004	5/12/2004	6/19/2006	36 20.82	145 59.25	5567
C3*	63	7/11/2005	6/19/2006	7/12/2005	6/19/2006	N/A	N/A	7/11/2005	6/19/2006	36 20.81	145 59.27	5567
C4	144	5/16/2004	5/2/2006	5/17/2004	5/2/2006	5/16/2004	5/3/2006	5/16/2004	6/23/2006	36 20.78	146 55.25	5631
C5	171	5/25/2004	11/21/2004	5/26/2004	11/21/2004	5/25/2004	12/27/2004	5/25/2004	6/23/2006	36 20.75	147 53.17	5846
C5	116	6/28/2005	6/23/2006	6/29/2005	6/23/2006	6/28/2005	6/23/2006	6/28/2005	6/23/2006	36 20.79	147 53.19	5798
C6	173	5/25/2004	6/22/2006	5/26/2004	6/22/2006	5/25/2004	4/24/2006	5/25/2004	6/22/2006	36 20.73	148 51.08	5888
D1	157	5/18/2004	12/18/2005	5/19/2004	12/18/2005	5/18/2004	12/19/2005	5/18/2004	6/16/2006	35 25.99	143 31.22	5719
D2	122	5/12/2004	3/25/2005	5/12/2004	3/25/2005	5/12/2004	3/26/2005	5/11/2004	7/14/2005	35 35.30	144 34.22	5821
D2*	155	7/14/2005	6/17/2006	7/15/2005	6/17/2006	N/A	N/A	7/14/2005	6/17/2006	35 35.20	144 34.40	5765
D3	104	6/24/2005	1/18/2006	6/25/2005	1/18/2006	6/24/2005	1/19/2006	6/24/2005	6/19/2006	35 35.42	145 31.58	5849
D4*	105	5/16/2004	6/24/2006	5/17/2004	6/24/2006	N/A	N/A	5/16/2004	6/24/2006	35 35.28	146 26.97	5969
D5	111	5/16/2004	10/6/2005	5/17/2004	10/6/2005	5/16/2004	10/7/2005	5/16/2004	6/23/2006	35 35.24	147 24.24	5845
D6	155	5/24/2004	6/16/2005	5/25/2004	6/16/2005	5/25/2004	6/18/2005	5/24/2004	6/28/2005	35 35.23	148 21.51	5968
D6	101	6/29/2005	2/19/2006	6/29/2005	2/19/2006	6/29/2005	2/20/2006	6/29/2005	6/22/2006	35 35.21	148 21.47	5945
E1	161	5/19/2004	6/15/2005	5/19/2004	6/15/2005	5/19/2004	6/17/2005	5/19/2004	7/15/2005	34 49.60	143 09.15	5315
E1*	122	7/15/2005	6/16/2006	7/16/2005	6/16/2006	N/A	N/A	7/15/2005	6/16/2006	34 49.65	143 09.30	5305
E2	162	5/19/2004	6/15/2006	5/20/2004	6/15/2006	5/19/2004	6/4/2006	5/19/2004	7/16/2006	34 49.59	144 05.81	5754
E3	121	5/11/2004	6/15/2006	5/12/2004	6/15/2006	5/11/2004	8/21/2005	5/11/2004	7/15/2006	34 49.60	145 02.59	5885

Continued on next page

Table 2 – continued from previous page

Site	SN	τ Start	τ End	P Start	P End	u, v Start	u, v End	Launch	Recovery	Lat	Lon	Depth
E4	68	6/25/2005	7/12/2005	6/26/2005	7/12/2005	N/A	N/A	6/24/2005	7/12/2005	34 49.59	145 59.27	5935
E4	137	5/13/2004	6/24/2005	5/14/2004	6/24/2005	5/13/2004	5/5/2005	5/13/2004	6/24/2005	34 49.63	145 59.27	5935
E4*	137	7/12/2005	6/25/2006	7/13/2005	6/25/2006	N/A	N/A	7/12/2005	6/25/2006	34 49.60	145 59.60	5935
E5	143	5/15/2004	8/20/2005	5/16/2004	8/20/2005	5/16/2004	8/21/2005	5/15/2004	6/9/2006	34 49.25	146 55.68	5800
E6	156	5/20/2004	3/9/2006	5/20/2004	3/9/2006	5/20/2004	7/9/2005	5/20/2004	6/10/2006	34 49.48	147 52.54	5943
E7	110	5/20/2004	9/17/2005	5/21/2004	9/17/2005	5/20/2004	9/17/2005	5/20/2004	6/11/2006	34 49.52	148 49.16	6110
E7	170	5/24/2004	5/9/2005	5/25/2004	5/9/2005	5/24/2004	5/10/2005	5/24/2004	7/3/2005	34 49.47	148 49.19	6138
E7*	170	7/7/2005	6/10/2006	7/7/2005	6/11/2006	N/A	N/A	7/6/2005	6/11/2006	34 49.50	148 49.22	6127
F1	114	5/29/2004	7/2/2005	5/30/2004	7/2/2005	5/29/2004	7/4/2005	5/29/2004	7/15/2005	34 00.58	143 26.02	5403
F2	136	5/11/2004	4/1/2005	5/11/2004	4/1/2005	5/11/2004	4/2/2005	5/11/2004	6/25/2005	33 55.15	144 37.40	5822
F2	102	6/25/2005	11/4/2005	6/26/2005	11/4/2005	6/25/2005	11/5/2005	6/25/2005	6/15/2006	33 55.15	144 37.37	5782
F3*	134	5/15/2004	3/22/2006	5/16/2004	3/22/2006	N/A	N/A	5/15/2004	6/25/2006	34 00.61	145 30.28	5796
F3*	147	5/16/2004	6/25/2006	5/14/2004	6/25/2006	N/A	N/A	5/15/2004	6/25/2006	34 00.62	145 30.28	5815
F4	142	5/15/2004	6/9/2005	5/15/2004	6/9/2005	5/15/2004	7/5/2005	5/14/2004	6/9/2006	34 00.64	146 28.21	5847
F5	158	5/23/2004	6/10/2006	5/24/2004	6/10/2006	5/24/2004	6/10/2006	5/23/2004	6/10/2006	34 00.60	147 24.25	6034
F6	174	5/24/2004	6/11/2006	5/24/2004	6/11/2006	5/24/2004	11/12/2005	5/24/2004	6/12/2006	33 50.99	148 14.68	6196
G1	115	5/29/2004	3/2/2006	5/30/2004	3/2/2006	5/29/2004	11/17/2005	5/29/2004	6/15/2006	33 11.44	144 06.43	5465
G2	119	5/10/2004	2/21/2006	5/11/2004	2/21/2006	5/10/2004	2/23/2006	5/10/2004	6/14/2006	33 11.46	145 01.92	5800
G3	138	5/14/2004	6/26/2005	5/14/2004	6/26/2005	5/14/2004	6/27/2005	5/13/2004	6/13/2006	33 11.49	145 59.25	5733
G4	109	5/14/2004	9/23/2005	5/15/2004	9/23/2005	5/14/2004	9/24/2005	5/14/2004	6/10/2006	33 11.53	146 56.52	5949
G5	149	5/25/2004	9/16/2005	5/24/2004	9/16/2005	5/23/2004	9/17/2005	5/23/2004	6/12/2006	33 11.48	147 51.98	6233
G6	107	5/21/2004	4/17/2005	5/22/2004	4/17/2005	5/21/2004	4/18/2005	5/21/2004	7/2/2005	33 11.47	148 47.35	6281
H2	118	5/9/2004	6/13/2006	5/10/2004	6/13/2006	5/9/2004	6/13/2006	5/9/2004	6/14/2006	32 22.19	144 34.17	5695
H3	112	4/29/2004	11/11/2005	4/30/2004	11/11/2005	4/29/2004	9/29/2005	4/29/2004	6/14/2006	32 22.24	145 30.87	5845
H4	132	5/14/2004	8/31/2005	5/14/2004	8/31/2005	5/14/2004	9/1/2005	5/14/2004	6/13/2006	32 22.26	146 27.56	5957
H5	168	5/22/2004	10/20/2005	5/24/2004	10/20/2005	5/22/2004	10/21/2005	5/22/2004	6/13/2006	32 22.24	147 24.25	6035
H6	166	5/22/2004	6/12/2006	5/23/2004	6/12/2006	5/22/2004	4/12/2006	5/22/2004	6/12/2006	32 22.33	148 20.99	5744

Continued on next page

Table 2 – continued from previous page

Site	SN	τ Start	τ End	P Start	P End	u, v Start	u, v End	Launch	Recovery	Lat	Lon	Depth
I1	163	5/29/2004	6/3/2006	5/29/2004	6/3/2006	5/29/2004	6/3/2006	5/28/2004	6/3/2006	31 29.45	144 05.23	5869
N1	160	5/26/2004	6/21/2006	5/27/2004	6/21/2006	5/22/2004	6/15/2006	5/26/2004	6/21/2006	38 30.76	148 20.32	5687
N1	45	7/4/2005	7/22/2005	7/5/2005	7/22/2005	7/4/2005	7/22/2005	7/4/2005	6/21/2006	38 30.87	148 20.47	5703
S1	101	4/28/2004	3/7/2005	4/27/2004	3/8/2005	4/26/2004	3/9/2005	4/26/2004	6/18/2005	30 00.93	143 18.15	5872
S1	36	6/18/2005	6/2/2006	6/19/2005	6/2/2006	6/18/2005	6/2/2006	6/18/2005	6/2/2006	30 01.13	143 18.31	5867
S2	102	4/27/2004	6/19/2005	4/27/2004	6/19/2005	4/27/2004	5/8/2005	4/27/2004	6/19/2005	30 36.55	143 36.86	5568
S2	43	6/19/2005	6/2/2006	6/20/2005	6/2/2006	6/19/2005	6/2/2006	6/19/2005	6/3/2006	30 36.67	143 36.98	5691

Table 2: CPIES/PIES serial numbers, periods of data coverage for τ, pressure and u, v, launch and recovery dates, positions, and deployment depths (m). An asterisk after the site designator denotes a PIES. All other instruements are CPIES.

Figure 3 summarizes the data coverage in time line format. Sites occupied by PIES, rather than CPIES do not have green lines in Figure 3. Dashed lines in Figure 3 indicate that only telemetry data were retrieved (C2, 2005 τ and pressure and S1, 2004 τ). Telemetered data are daily averages of the variables τ, detided pressure, and currents. The daily pressure data are detided inside the instrument with a Godin filter before being telemetered [*URI*, 2002]. Temperature data are not telemetered.

A number of instrument problems were identified and fixed during both the deployment and telemetry cruises. During the deployment cruise in 2004, the primary causes of failure were seawater leaks through the vacuum port and acoustic command system problems. During the telemetry cruise in 2005, new problems included battery passivation and water shorts in current meter cables. After recovery in 2006, it was determined that the factory had miswired the battery stacks.

Table 3 summarizes the instruments that were lost or abandoned as well as those that were recovered and subsequently redeployed.

Site	SN	Launch	Recovery	Latitude	Longitude	Depth	Comment
			Lost/Abandoned Instruments				
D3	150	5/12/2004	Abandoned	35 35.32	145 31.51	5849	
E6	146	5/20/2004	Abandoned	34 49.50	147 52.56	5943	
G2	108	4/30/2004	Lost	33 11.49	145 01.91	5800	
G2	130	4/30/2004	Lost	33 11.49	145 01.92	5800	
			Redeployed Instruments				
C5	45	6/28/2005	6/28/2005	36 20.70	147 53.36	5798	Later launched at N1
D5	117	5/6/2004	5/6/2004	35 35.21	147 24.27	5845	
F2	120	5/10/2004	5/10/2004	33 55.12	144 37.39	5822	
F4	114	5/5/2004	5/5/2004	34 00.63	146 28.22	5847	Later launched at F1
F4	141	5/14/2004	5/14/2004	34 00.65	146 28.21	5847	
G1	110	5/8/2004	5/8/2004	33 11.42	144 06.40	5465	Later launched at E7
H1	108	4/27/2004	4/27/2004	32 22.16	143 38.17		Later launched at G2 and lost
H1	109	5/8/2004	5/8/2004	32 22.18	143 38.11		Later launched at G4
H2	111	5/9/2004	5/9/2004	32 22.21	144 34.17	5695	Later launched at D5
H3	63	6/20/2005	6/20/2005	33 22.24	145 30.87	5845	Later launched at C3 without CM
I1	107	5/8/2004	5/8/2004	31 29.42	144 05.21	5869	Later launched at G6
I1	115	5/28/2004	5/28/2004	31 29.43	144 05.24	5869	Later launched at G1
I2	136	5/9/2004	5/9/2004	31 29.46	145 03.15		Later launched at F2

Table 3: Lost, abandoned and redeployed instruments. Deployment depths are in meters.

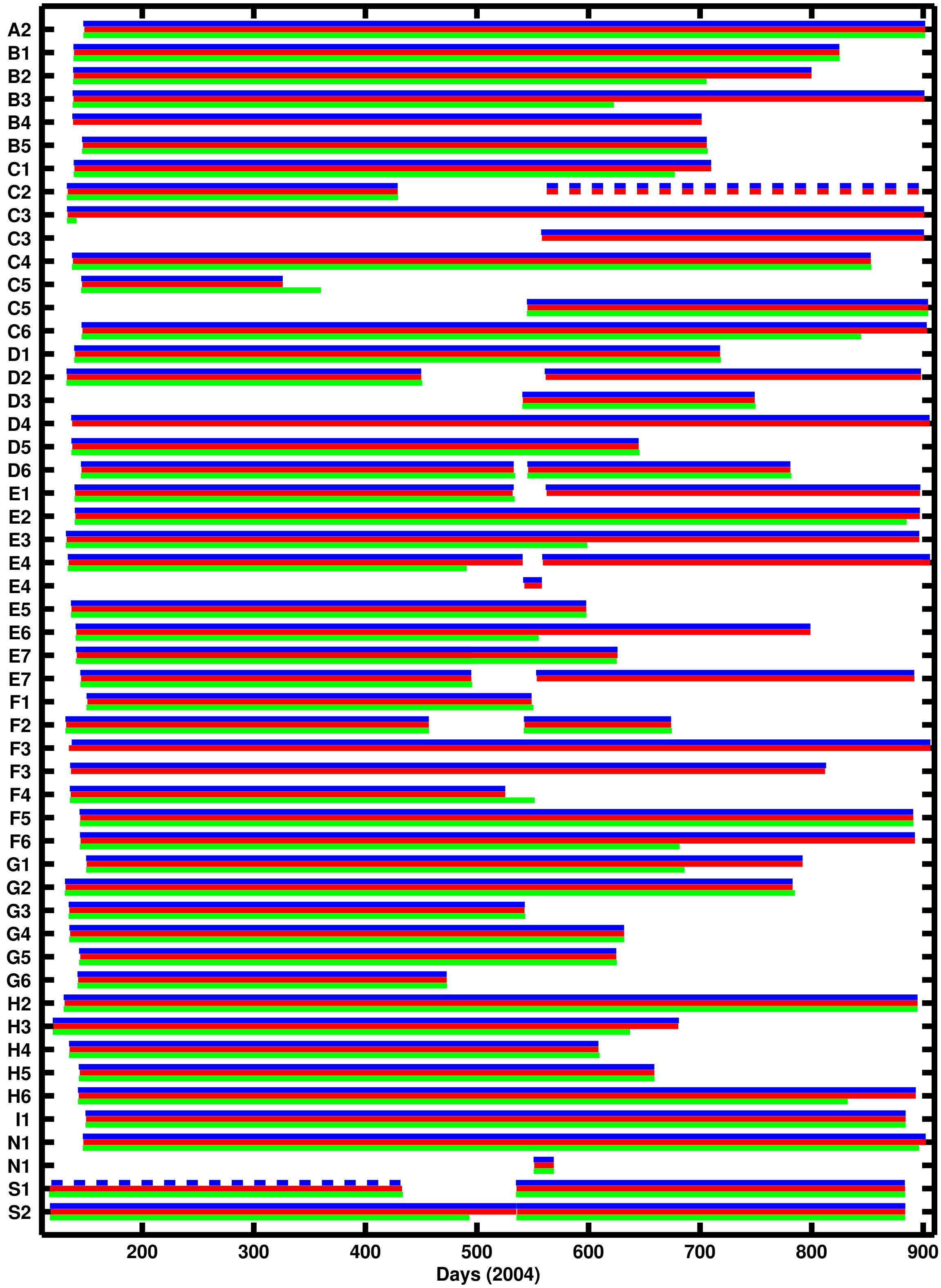


Figure 3: Site timeline. Periods of data coverage are shown for each site for τ (blue), pressure (red), and u, v (green). Dashed lines indicate telemetry data only (C2, 2005 τ and pressure and S1, 2004 τ).

2 Data Processing and Calibration

2.1 Overview

Initial data processing was carried out with a series of MATLAB routines (IESpkg3) specifically developed for IES data [*Kennelly et al.*, 2007]. The steps are described below and schematically illustrated in Figure 4. τ, pressure and Paroscientific temperature are windowed and despiked similarly (Steps 1 and 2 in Figure 4). Pressure is additionally detided and dedrifted (Steps 3-5, Figure 4). DCS u, v and temperature are processed separately (Step 6, Figure 4). A fourth order lowpass Butterworth filter was applied forward and backward to all data records with a cutoff period of 3 days (Step 7, Figure 4). The filter was run forward and backward to eliminate phase offsets and the initial and ending records were excluded to avoid startup transients. The filtered output was subsampled at half day intervals (0000 and 1200 UT).

After initial processing was complete, the pressure records were again dedrifted and leveled using the current data. This is a new technique and is described in Section 2.3.4.

Finally, "site best" files were constructed to attain a single two year long record of the measurements at each site. For 35 sites, a single instrument/deployment makes up the "site best" file (A2, B1, B2, B3, B4, B5, C1, C3 (SN 124), C4, C6, D1, D3, D4, D5, E2, E3, E5, E6, F1, F4, F5, F6, G1, G2, G3, G4, G5, G6, H2, H3, H4, H5, H6, I1, and N1). Sites where an instrument was deployed in 2004, recovered and redeployed in 2005, with final recovery in 2006 were combined to make a long time series. If multiple instruments were deployed, the "site best" file consists of the best quality and longest records. Overlapping data from C3 (SN 63) and N1 (SN45) were not included in any "site best" files. Table 4 summarizes the sites where more than one instrument was needed to create the "site best" file.

Site	IES SN	Comment
C2	131, 068	
C5	171, 116	
D2	122, 155	
D6	155, 101	
E1	161, 122	
E4	137, 68, 137	3 segments
E7	110, 170	prs and tau use 110 and non-overlapping portion of 170
		currents use 170 and portion of 110
F2	136, 102	
F3	147, 134	147 used for prs and tmp, 134 used for tau
S1	101, 036	no tau for 2005 because there was no calibration CTD
S2	102, 043	

Table 4: Instruments used to construct Site Best Files for locations using multiple instruments.

Although not shown in this report, "site best" files of calibrated, lowpass filtered, subsampled (0000 and 1200 UT), leveled pressure, τ_{0-1400}, and currents are included on the accompanying data CD.

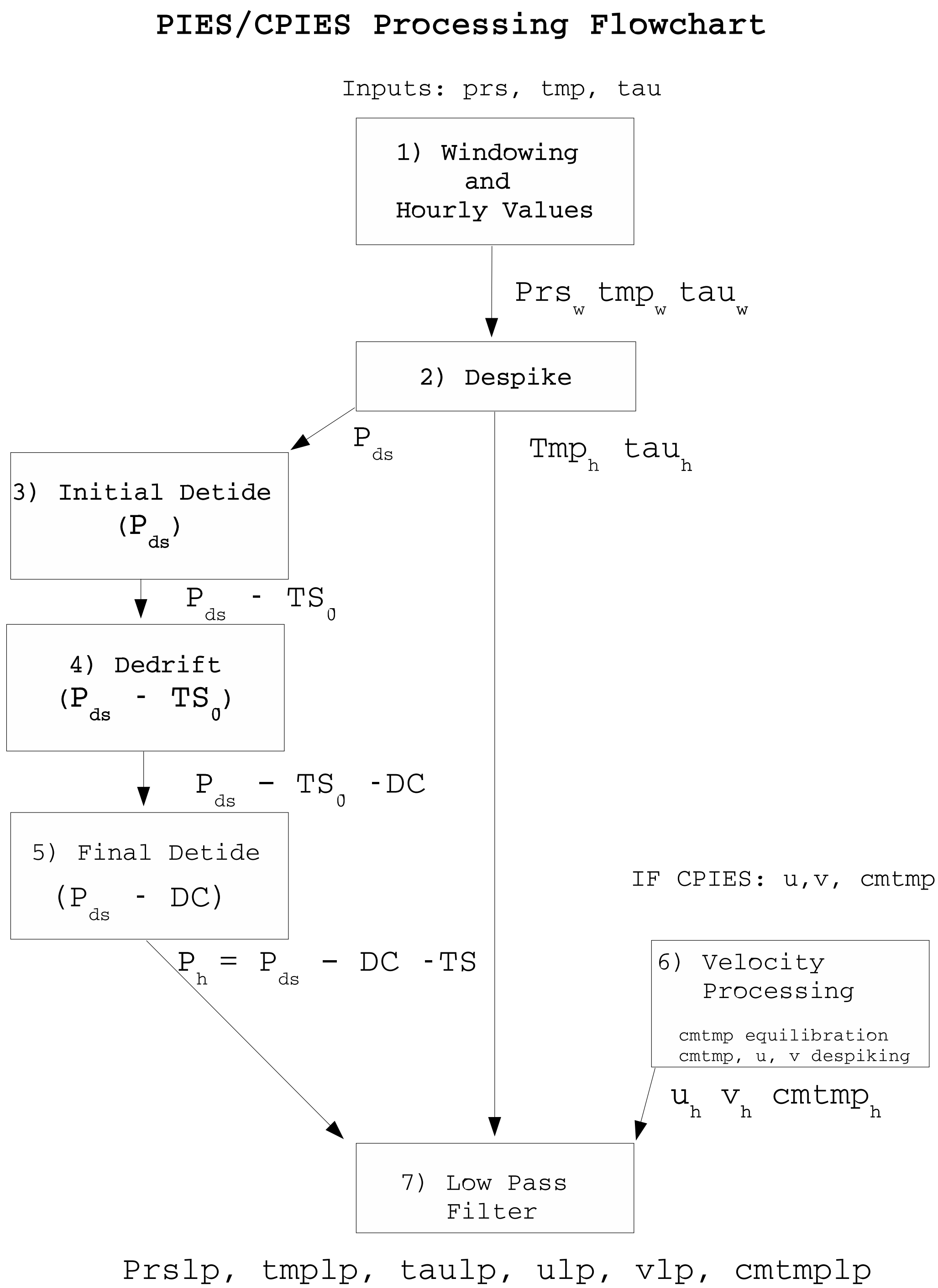


Figure 4: IES Data Processing Flowchart.

2.2 Travel Time

A representative travel time for each hour was selected using a modified quartile method (Step 1, Figure 4). Using this method, each hourly burst of 24 τ measurements was passed through two stages of windowing to eliminate outliers and to reduce noise. Details of this method can be found in *Kennelly et al.* [2007]. Large spikes were subsequently removed from the hourly travel time record (Step 2, Figure 4). Hourly travel time data were lowpass filtered using a fourth order Butterworth filter with a cutoff period of 3 days. The filter was run forward and backward to eliminate phase offsets and the initial and ending records were excluded to avoid startup transients. The filtered output was subsampled at half day intervals (0000 and 1200 UT).

It is convenient to have all the travel time data referenced to a common pressure level (τ_{index}) for subsequent scientific analyses. The τ_{index} are used with look-up tables (GEM) calculated from historical regional hydrography to obtain time series of full-water-column temperature, salinity and specific volume anomaly at each site. For the KESS data set, τ_{index} was integrated between 0-1400 dbar. The interval 0-1400 dbar was dictated by a large number of floats in the KESS region that profiled to a maximum depth of only 1400 dbar. The conversion of measured τ (τ_m) to τ_{index} at each site entailed several steps, which are outlined here and detailed below. A summary of the estimated errors in τ_{0-1400} follows.

1. Remove the mass-loading contribution τ_p from τ_m to isolate the steric contribution τ_s
2. Convert τ_s to dynamic tau (τ_s^*)
3. Remove the seasonal variation in τ_s^* to produce $\tau_{s,ds}^*$
4. Determine calibration offsets to convert $\tau_{s,ds}^*$ to τ_{0-4000}
5. Convert τ_{0-4000} to τ_{index} (or τ_{0-1400})

2.2.1 Mass-loading and steric contributions to τ_m

Contributions to τ_m arise from two sources: a steric component (baroclinic, τ_s) and a mass-loading or path length component (barotropic, τ_p):

$$\tau_m = \tau_s + \tau_p \tag{1}$$

Maximum deep pressure variability of about 0.2 dbar contributed mass-loading round-trip travel times near 0.2 ms, which are small relative to the observed τ_m variations of about 25-30 ms. Nevertheless, the hydrographic measurements used to construct the GEM look-up tables only determine steric height changes. Thus, we want to remove the mass-loading contribution from the measurements to obtain τ_s. The steric contribution is obtained from the lowpass-filtered, subsampled measured τ (τ_m) by

$$\tau_s = \tau_m - \tau_p \tag{2}$$

for which

$$\tau_p = 2 \cdot p/(\rho \cdot g \cdot c) \tag{3}$$

where p is the dedrifted, but not detided bottom pressure, c is the speed of sound, g is gravitational acceleration and ρ is density.

2.2.2 Dynamic τ

In an analogy with dynamic height, using regional hydrographic data we calculate a dynamic τ (which we designate as τ^*) that does not include a latitudinal dependence on g. Round-trip travel time τ between the surface and a reference pressure P_{ref} is defined by

$$\tau = 2\int_0^{P_{ref}} \frac{1}{c\rho g} dp' \tag{4}$$

where c is the speed of sound and ρ is the density. Gravitational acceleration, g, a function of latitude λ and depth z, can be expressed by the relation provided in *Gill* [1982]

$$g(\lambda, z) = (9.78032 + 0.005172 \sin^2 \lambda - 0.00006 \sin^2 2\lambda) \frac{1}{(1 + \frac{z}{a})^2} \tag{5}$$

where a is the earth's radius, and z is depth. Two hydrocasts with identical water properties can differ by milliseconds within the KESS region due simply because of different latitude. Therefore, by choosing $P_{ref} = 1400$ dbar, τ_{0-1400} calculated from the historical hydrographic database for the GEM look-up table assumed that $g \equiv 9.8 \ \text{m s}^{-2}$

$$\tau^* = \frac{1}{9.8}\int_0^{P_{ref}} \frac{2}{c\rho} dp' \tag{6}$$

Depth and latitude dependent gravity is inherent in the travel times measured by the CPIES, and the conversion to dynamic τ required the following empirical approach. Gravitational acceleration's depth and latitude dependence can be separated by

$$g(\lambda, z) = G(\lambda)H(z) \quad where \quad G(\lambda) = g(\lambda, 0) \quad and \quad H(z) = \frac{1}{(1 + \frac{z}{a})^2} \tag{7}$$

With a=6,371,000 m, H remains very close to but not exactly unity for typical ocean depths. It is straightforward to take $G(\lambda)$ outside the integral.

$$\tau = \frac{1}{G(\lambda)}\int_0^{P_{ref}} \frac{2}{c\rho H(z)} dp' \tag{8}$$

For CPIES, P_{ref} is set to P_b, the average measured bottom pressure. We assumed H could be taken out of the integral and expressed as a function of pressure,

$$\tau = \frac{1}{G(\lambda)} \overline{\left(\frac{1}{H}\right)}_{P_b} \int_0^{P_b} \frac{2}{c\rho} dp' \quad or \quad \tau = \frac{9.8}{G(\lambda)} \overline{\left(\frac{1}{H}\right)}_{P_b} \tau^* \tag{9}$$

The hydrographic database empirically determined $\overline{\left(\frac{1}{H}\right)}_{P_b}$ by

$$\overline{\left(\frac{1}{H}\right)}_{P_b} = \left(\frac{g(\lambda, 0)}{9.8}\right)\left(\frac{\tau}{\tau^*}\right) \tag{10}$$

for which we approximate

$$\overline{\left(\frac{1}{H}\right)}_{P_b} = \left(1 - \frac{P_b}{1.017 \cdot a}\right) \tag{11}$$

substituting in 9 yields

$$\tau = \frac{9.8}{G(\lambda)}\left(1 - \frac{P_b}{1.017 \cdot a}\right)\tau^* \tag{12}$$

and rearranging produces the following expression to convert measured τ to dynamic τ

$$\tau^* = \tau_m \cdot \frac{g(\lambda, 0)}{9.8 \cdot \left(1 - \frac{P_b}{1.017 \cdot a}\right)} \tag{13}$$

For each KESS record, we replaced τ_m by τ_s in Equation 13 to yield τ_s^*.

2.2.3 Remove seasonal fluctuations

Travel times measured by the CPIES vary in response to seasonal warming and cooling of the surface layers. To minimize these seasonal fluctuations, we removed the average seasonal variation in τ for the upper 250 dbar from the τ_s^* records.

Cross-frontal changes in τ_{0-250} overwhelm the seasonal variability, so we first isolated the seasonal changes as the residual from the τ_{0-250} to $\tau_{250-1400}$ curve (Figure 5, top), determined by cubic spline interpolation. To compute the annual progression, the residuals were first grouped into 15-day-overlapping bins (50% overlap), and then averaged. The resulting curve (Figure 5, bottom) was smoothed using a lowpass filter with a 100-day cutoff period. The annual curve was then subtracted from τ_s^* to remove the average seasonal variation, producing $\tau_{s,ds}^*$. The amplitude of the seasonal cycle was 1 ms with an rms of 0.66 ms (Figure 5).

2.2.4 Calibrate to τ_{0-4000}

In previous experiments, measured travel times were converted to τ_{index} using a linear relationship and coincident hydrographic measurements. Historical hydrography provided the relationship between τ measured from the seafloor and those at the common reference level, and calibration CTDs taken at launch and recovery provided the offset.

In KESS, a different approach was needed. Although between one and three calibration CTD casts were taken at each site, many of them did not extend deep enough to apply the earlier methods without introducing intermediate steps.

First, the calibration CTD measurements were integrated over their full depth range to the end of cast (EOC) to obtain $\tau_{CTD_{0-EOC}}$ and the seasonal variations removed. End of cast pressures were rounded to the nearest shallower 50 dbar increment. Next, $\tau_{CTD_{0-EOC}}$ was converted to $\tau_{CTD_{0-4000}}$. Subsequently, the calibration offset (C_{IES}) for each travel time record at each CPIES site was determined as

$$C_{IES} = \tau_{CTD_{0-4000}} - \langle \tau_{s,ds}^* \rangle \tag{14}$$

where $\langle \tau_{s,ds}^* \rangle$ is the average of six hourly samples centered on the time of the CTD. Here we assume that the only differences between $\tau_{CTD_{0-4000}}$ and travel times measured by the instruments on the seafloor are due to differences in path length, which is reasonable since the waters in the deep North Pacific exhibit nearly uniform temperature and salinity gradients. If more than one calibration CTD was available for a record, the C_{IES} values were averaged.

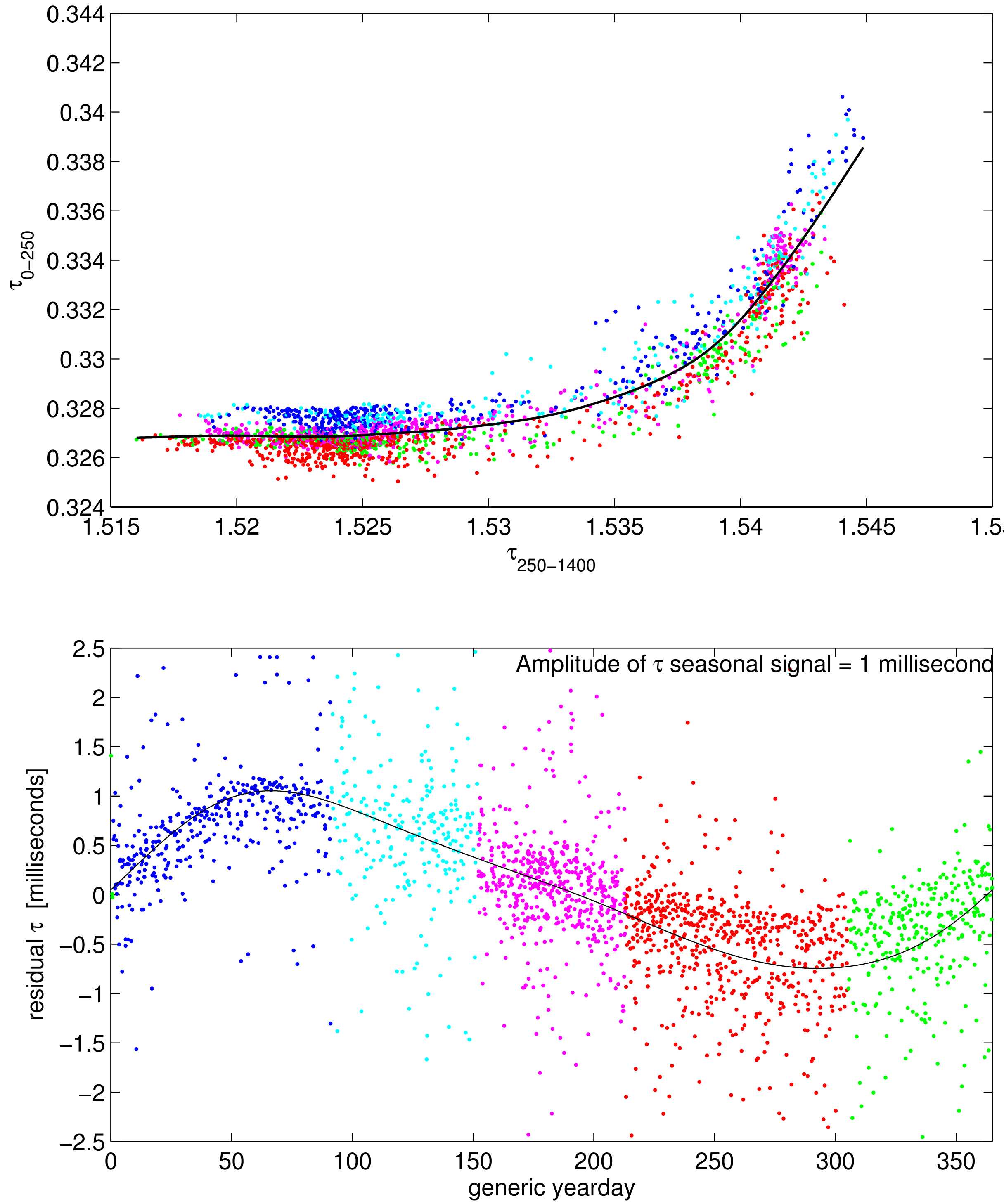


Figure 5: (top) The cross-frontal dependence of acoustic travel time through the upper 250 dbar upon $\tau_{250-1400}$ calculated from hydrography. (bottom) The residuals from top are plotted as a function of yearday (dots). Dots have been color-coded to highlight time of year. The annual march curve (bottom) is subtracted from τ^*_s to produce $\tau^*_{s,ds}$ a deseasoned τ.

In turn, the calibration offsets were added to the time series of lowpass-filtered $\tau^*_{s,ds}$ for each instrument, effectively turning them into τ_{0-4000}. Calibration offsets were not calculated for all measured travel time records, however. Site S1 (SN 101, 2004-2005 deployment) lacked the necessary CTDs to calculate C_{IES}. For sites with coincident measurements from multiple instruments (C3, E7, F3, and N1), only one record of τ_{0-1400} was needed for the subsequent mapping procedure (not documented here). For these sites, C_{IES} was calculated only for the longest and/or highest quality τ record. Table 5 lists the calibration offsets by site.

Table 5

Site	IES SN	C_{IES}
A2	145	-2.2476
B1	151	-2.0536
B2	152	-1.9082
B3	148	-2.1475
B4	164	-2.2061
B5	167	-2.3266
C1	153	-2.1943
C2	131	-2.2788
C2	68	-2.2846
C3	124	-2.0725
C4	144	-2.1637
C5	171	-2.4007
C5	116	-2.4042
C6	173	-2.4646
D1	157	-2.3118
D2	122	-2.3805
D2	155	-2.3803
D3	104	-2.4546
D4	105	-2.6804
D5	111	-2.4256
D6	155	-2.6008
D6	101	-2.6082
E1	161	-1.7875
E1	122	-1.7866
E2	162	-2.3076
E3	121	-2.4698
E4	137	-2.6184
E4	68	-2.6115
E4	137	-2.6089
E5	143	-2.3926
E6	156	-2.6209
E7	110	-2.8384
E7	170	-2.8381
F1	114	-1.9307
F2	136	-2.3975
F2	102	-2.3965

Continued on next page

Table 5 – from previous page

Site	IES SN	C_{IES}
F3	134	-2.4260
F4	142	-2.4956
F5	158	-2.7074
F6	174	-2.9160
G1	115	-2.0635
G2	119	-2.3592
G3	138	-2.3524
G4	109	-2.5902
G5	149	-2.9668
G6	107	-3.0472
H2	118	-2.2217
H3	112	-2.4733
H4	132	-2.6385
H5	168	-2.7044
H6	166	-2.3303
I1	163	-2.4875
N1	160	-2.2943
S1	36	-2.5875
S2	102	-2.1773
S2	43	-2.1829

Table 5: Calibration offset (C_{IES}) for each site.

2.2.5 Convert τ_{0-4000} to τ_{0-1400}

The final step was to scale the CPIES time series of τ_{0-4000} into time series of τ_{0-1400}. For this step, we empirically determined a polynomial relationship between τ_{0-1400} and τ_{0-4000} (Figure 6) using historical hydrographic measurements from which the seasonal fluctuations were removed. We selected all CTDs and profiling floats within the geographic region delineated by 30-40 °N and 143-149 °E, spanning the time period 1976–2006. In addition, several deep-reaching CTDs taken near 41.5 °N were included. The fitted polynomial was

$$\tau_{0-1400} = a \cdot \tau_{0-4000}^3 + b \cdot \tau_{0-4000}^2 + c \cdot \tau_{0-4000} + d \qquad (15)$$

where $a = -78.5126$, $b = 1241.0283$, $c = -6537.89$, and $d = 11480.9442$. Utilizing this relationship, time series of τ_{0-4000} were converted into τ_{0-1400}. A single time series of τ_{0-1400} was calculated for each site from the best data available for that site. Although not shown here, the time series of τ_{0-1400} are included on the data CD accompanying this report.

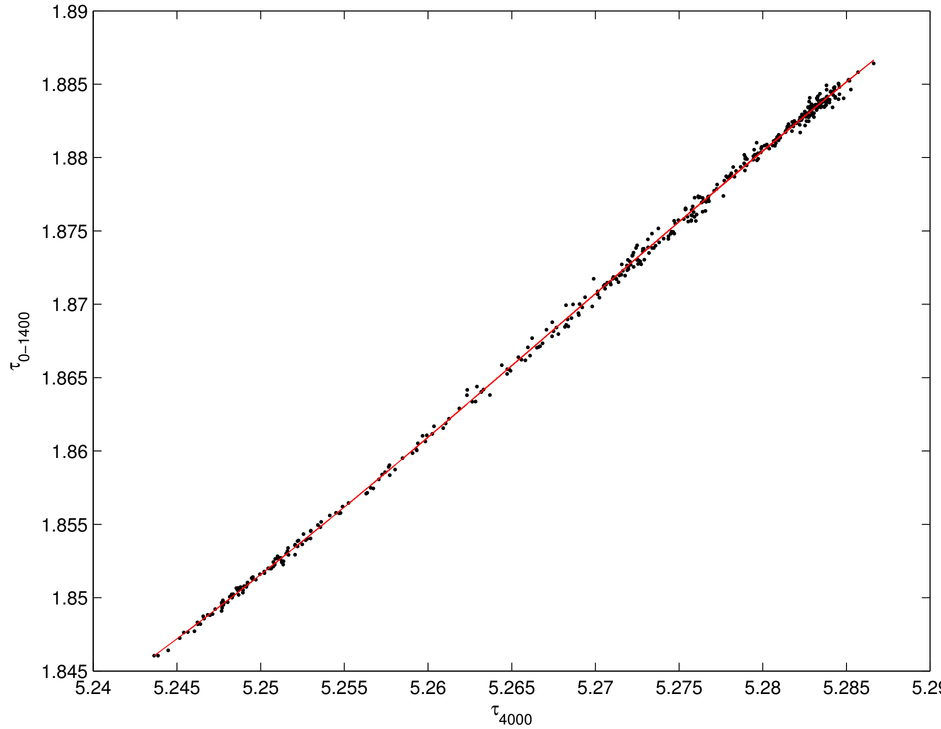


Figure 6: Polynomial relationship between τ_{0-4000} and τ_{0-1400} calculated from hydrographic measurements in the KESS region with seasonal variations removed.

2.2.6 τ_{0-1400} error estimates

Errors derived from uncertainty in

1. the scatter in the τ measurement, 0.05 ms.

$$error_{scatter} = \frac{\tau_{scatter}}{\sqrt{24\frac{samples}{hour} * 72\,hr}} \tag{16}$$

$$where\ \tau_{scatter} = individual\ \tau_m\ scatter,\ 2.2\,ms \tag{17}$$

2. the mass-loading contribution, 0.02 ms,

$$error_{mass-loading} = \frac{2 * dp'}{\rho * g * c} \tag{18}$$

$$where\ dp' = 1.4\,cm \tag{19}$$

3. the conversion from τ to τ^*, 0.05 ms,

$$error_{\tau_{conversion}} = 6\,ppm * 8\,s \tag{20}$$

4. the seasonal correction 0.66 ms, see Section 2.2.3

5. the conversion from τ^* to τ_{index}, 0.7 ms, and
6. the calibration curve τ_{0-1400} and τ_{0-4000}, 0.34 ms.

The conversion from τ^* error estimate (item 5 in the above list) considered a possible spatial offset between the hydrocast and IES, internal tides variability, deep density variability beneath 4000 m depth, error in deseasoning, and error in the τ^* calculation. The six-listed errors are independent, so the total error in IES-measured τ_{0-1400} is

$$\sqrt{{\varepsilon_1}^2 + {\varepsilon_2}^2 + {\varepsilon_3}^2 + {\varepsilon_4}^2 + {\varepsilon_5}^2 + {\varepsilon_6}^2} \tag{21}$$

$$= \sqrt{.05^2 + .02^2 + .05^2 + .66^2 + .7^2 + .34^2} = 1.02\,\text{ms}. \tag{22}$$

Comparisons with τ_{0-1400} measured by the profiling floats indicated that this error was a reasonable estimate.

2.3 Bottom Pressure

2.3.1 Windowing and Despiking

Pressure data were windowed to remove outliers and hourly means were calculated (Step1, Figure 4). Large spikes were then removed from the data (Step 2, Figure 4).

2.3.2 Detiding

Initial detiding (Step 3, Figure 4) removed the tidal contribution (semi-diurnal, diurnal and longer period constituents) from the pressure records (despiked but still containing drift) using a FORTRAN program called RESPO (Response Analysis of Tides), based on the work of *Munk and Cartwright* [1966]. After the pressure record has been dedrifted, it is customary to detide the record again to improve the tide prediction. This second pass (Step 5, Figure 4) adds the tides removed by initial detiding to the dedrifted pressure record and then recalculates the tides. For the KESS data set, the drift calculation was further refined after comparison with current data (see Section 2.3.4). Once the best estimates of drift had been calculated and removed, the pressure records were detided a final time, removing the semi-diurnal and diurnal constituents only. It was determined that the Mf (fortnightly) tide which has an amplitude of order 3-6 mm [*Schwiderski*, 1982] could not be removed with confidence throughout the KESS array because of low signal to noise ratios. Hence, the long period tides were not removed from the final pressure records.

The amplitudes and phases of the diurnal and semi-diurnal tidal constituents for the KESS area are contoured in Figures 7 and 8 (Table 10 in Section 4 list the amplitudes and phases for each site). Minimum, maximum, range and mean amplitude are summarized for the diurnal and semi-diurnal tidal constituents in Table 6. One file for each site was used to calculate these statistics. For sites which have multiple instruments, the one with the longest time series was used.

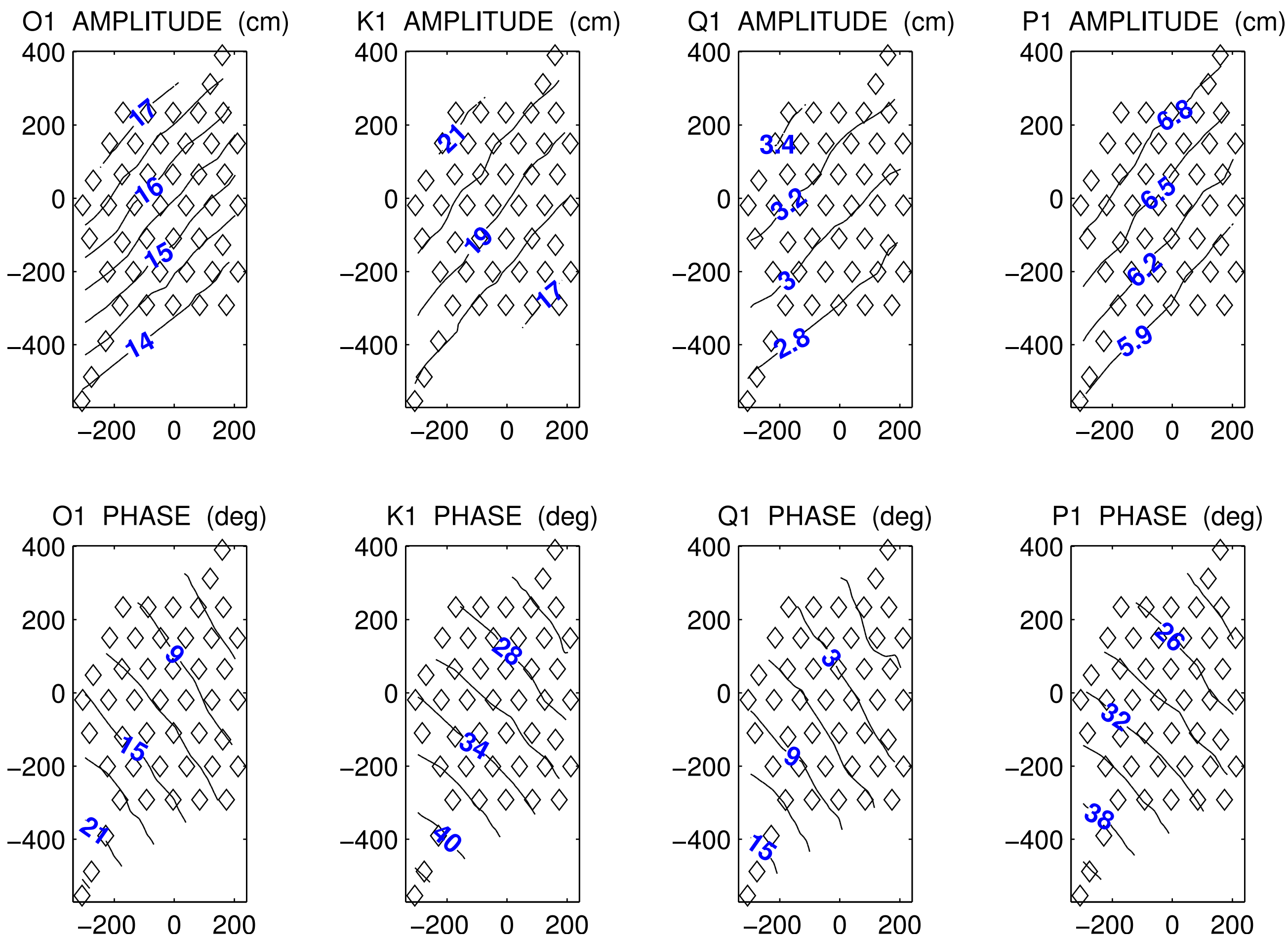


Figure 7: Amplitudes (top) and phases (bottom) of the major diurnal tidal constituents contoured for the KESS area. Diamonds indicate the CPIES/PIES locations.

Tidal Constituent	Min (cm)	Max (cm)	Range (cm)	Mean (cm)
O1	13.15	17.33	4.18	15.48
K1	16.41	21.27	4.87	19.06
Q1	2.32	3.42	1.10	3.05
P1	5.55	7.12	1.57	6.38
M2	15.53	25.14	9.61	20.57
K2	2.42	3.40	0.98	2.93
N2	1.09	3.26	2.18	2.29
S2	8.77	12.45	3.68	10.71

Table 6: Minimum, maximum, range and mean amplitude for the diurnal and semi-diurnal tidal constituents for the KESS sites.

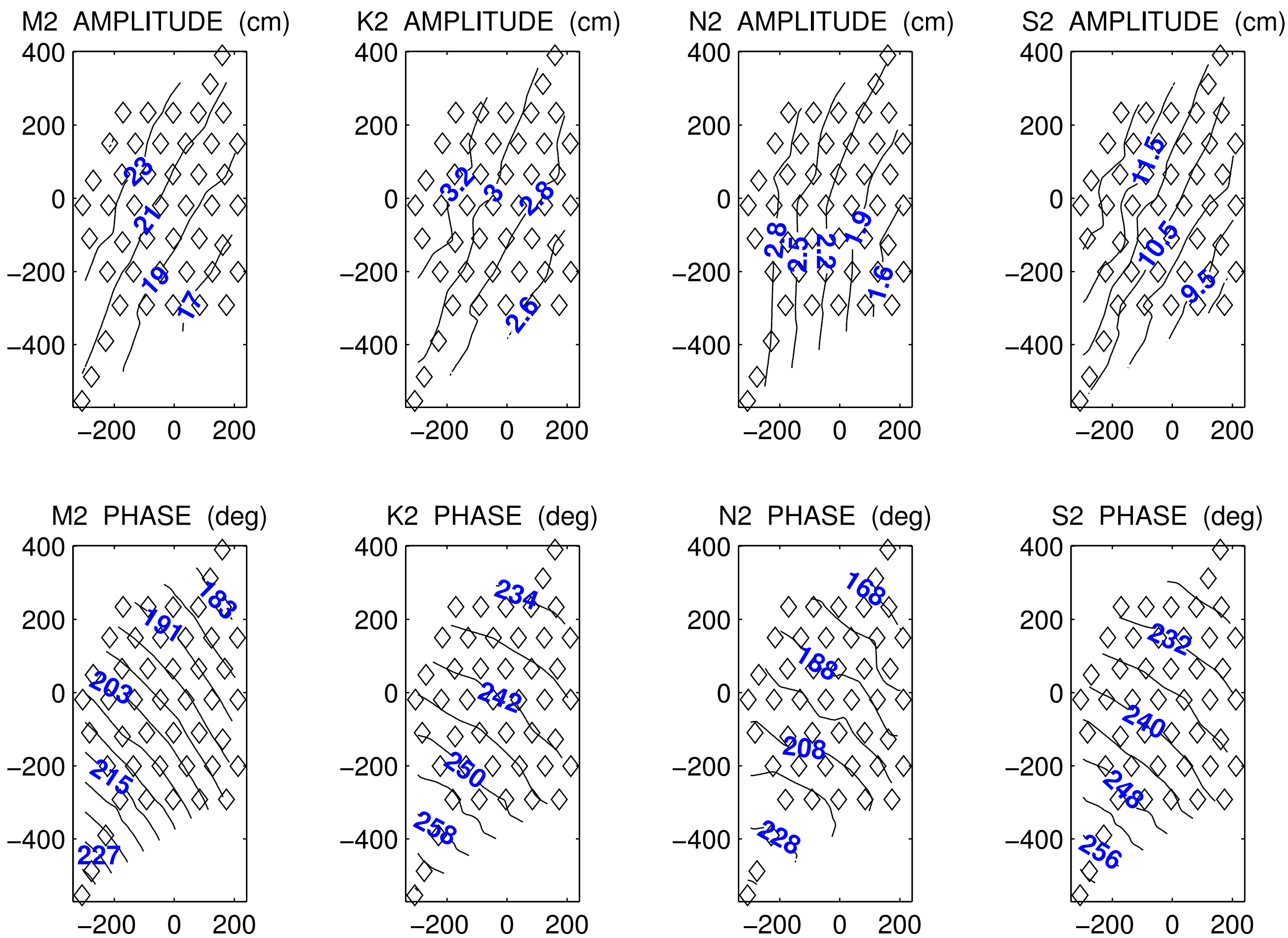


Figure 8: Amplitudes (top) and phases (bottom) of the major semi-diurnal tidal constituents contoured for the KESS area. Diamonds indicate the CPIES/PIES locations.

2.3.3 Initial Dedrifting

"Drift" refers to a temporal change in pressure calibration. Drifts are typically associated with variations in the properties of the pressure sensor crystal over long timescales or slight imperfections in the IES master clock. The dedrifting step fits a functional form to the data and then removes it from the pressure record (Step 4, Figure 4). These drifts are preliminary and are removed to improve the tide prediction. The next section describes how improved estimates of instrumental drifts are obtained using current measurements to provide independent estimates of true ocean signals.

2.3.4 Dedrifting/Leveling to Current Meter Data

Real ocean signals may appear like instrumental drift. To distinguish drift from real ocean signals, comparisons were made with coincident current measurements, as outlined here.

1. Short term variability was eliminated by lowpass filtering the bottom currents using a fourth order Butterworth filter with a 31 day cutoff. The filtered currents were objectively mapped to determine twice-daily estimates of the deep stream function at each CPIES location. The mapped stream functions were scaled to pressure units (P_{cm}).
   a. Pressures at sites B5, E2, and H2 were also included to reference the maps. Preliminary processing with the standard package removed the means, tides, and drift from these records. The daily array-wide averaged pressure (the basin average, BA, calculated using 15 full-term pressure records) was also removed.
   b. Mapping parameters included a Gaussian correlation length of 100 km and error estimates of 0.05.
   c. Mapping was performed using inputs fu, fv, p/f, where f is the Coriolis parameter.
2. The preliminary drift curves (from Section 2.3.4) were added back to the pressure time series at each CPIES site (P_{cpies}) and the BA was removed. These records were lowpass filtered in the same manner as the bottom currents (Step 1).
3. Time series of reference pressure (P_{ref}) were calculated for each CPIES site as $P_{ref} = P_{cm} - P_{cpies}$.
4. The dedrift program was run on P_{ref} to obtain an estimate of the drift (P_{drift}).
5. Dedrifted pressures were calculated as $P'_{cpies} = P_{cpies} - P_{drift}$.
6. Time series of P_{ref} were recalculated as $P_{ref} = P_{cm} - P'_{cpies}$.
7. Steps 3-6 were repeated until the slope of P_{ref} was smaller than $\pm 10^{-5}$ dbar/day. This criterion ensures that the residual error due to drift will be less than 1 cm at the end of the 2-year time period.

For all instruments, good agreement with current data was achieved using Equation 23.

$$Drift = A \cdot e^{Bt} + C \cdot t + D \tag{23}$$

For some instruments (A2, C2 2004, E1 2005, E4a, E7a, G1, G2, G6 and N1a) a linear fit, where the A and B coefficients of Equation 23 equal zero, provided the best estimate of the drift. A fortuitous consequence of this procedure is that the dedrifted pressures are also referenced to the same absolute geopotential and can be mapped without additional leveling procedures.

2.4 Temperature

2.4.1 Paroscientific Temperature

A Paroscientific temperature sensor is a component of all PIES/CPIES. This sensor is located inside the glass sphere (Figure 2, bottom sphere) and therefore does not provide an accurate measurement of the instantaneous in situ water temperature.

Temperature data were windowed to remove outliers and hourly means were calculated (Step 1, Figure 4). Typically, it takes from 12 to 24 hours after launch for the temperature inside the glass sphere to reach equilibrium with the surrounding water. Thus, temperature and pressure data acquired prior to reaching equilibrium were discarded. Large spikes were then removed from the temperature record (Step 2, Figure 4).

So that temperature variations may be compared with DCS temperature variations, a linear fit (Equation 24) was removed from each hourly record. Tables listing the coefficients of the linear fits are included in Section 5.1. Detrended hourly temperature data were lowpass filtered using a fourth order Butterworth filter and subsampled at half day intervals.

$$Fit = A_T \cdot t + B_T \qquad where \quad t = time(days) \tag{24}$$

2.4.2 DCS Temperature

Hourly averages for the Aanderaa DCS temperature records were calculated (Step 6, Figure 4). This step starts with determining when the DCS temperature reached equilibrium with the surroundings (similar to temperature processing for the Paroscientific temperature sensor described in Section 2.4.1). However, equilibration occurs more rapidly than for the Paroscientific sensor because the DCS temperature sensor is in direct contact with the water. Large spikes were subsequently removed from temperature. A linear fit (Equation 24) was also removed from each DCS temperature record for the purpose of intercomparison. Tables listing the coefficients for the linear fits removed from each DCS temperature record are included in Section 5.2. Detrended hourly DCS temperature data were lowpass filtered using a fourth order Butterworth filter and subsampled at half day intervals.

2.5 Currents

Hourly averages for the Aanderaa DCS velocity components were calculated (Step 6, Figure 4). Large spikes were subsequently removed from u and v.

A number of corrections were applied to the hourly current data. First the u, v velocities were converted to speed and direction. Next, the directions were adjusted for the magnetic declination at the locations of the CPIES sites. Magnetic declination varied over the array from $3\,^{\circ}57'W$ at site H6 to $6\,^{\circ}33'W$ at site B1 (Table 7).

Site	Degrees	Minutes	Direction	Site	Degrees	Minutes	Direction
A2	6	0	W	E6	4	57	W
B1	6	33	W	E7	4	42	W
B2	6	20	W	F1	5	42	W
B3	6	7	W	F2	5	25	W
B4	5	52	W	F3	5	15	W
B5	5	37	W	F4	5	1	W
C1	6	23	W	F5	4	47	W
C2	6	11	W	F6	4	30	W
C3	5	58	W	G1	5	16	W
C4	5	44	W	G2	5	4	W
C5	5	29	W	G3	4	51	W
C6	5	13	W	G4	4	37	W
D1	6	11	W	G5	4	22	W
D2	6	1	W	G6	4	8	W
D3	5	48	W	H2	4	52	W
D4	5	35	W	H3	4	40	W
D5	5	21	W	H4	4	26	W
D6	5	5	W	H5	4	12	W
E1	6	2	W	H6	3	57	W
E2	5	51	W	I1	4	40	W
E3	5	39	W	N1	6	6	W
E4	5	25	W	S1	4	18	W
E5	5	12	W	S2	4	27	W

Table 7: Magnetic declination for KESS Sites

Next, the current speed was multiplied by a sound speed scale factor. This adjustment was necessary because the DCS used a default value of 1500 m s^{-1} for sound speed when measuring the currents in situ. Because actual sound speed varies with oceanic region and water depth, a small error in current strength is introduced by using this nominal sound speed. Sound speeds for the deep ocean in the KESS region were calculated using CTDs taken on the cruise. The appropriate sound speed was found for each instrument, where the depth of each DCS was specified as 50 m shallower than the average pressure at the site (see Figure 2 schematic). The correction factor is a ratio of the true sound speed and the nominal value. For the KESS instruments at depths of 5300–6400 m, sound speeds were 1544.83–1564.64 m s^{-1} and the correction factors were 1.029–1.043.

Current speeds were subsequently adjusted for current meter bias based on the work of *Hogg and Frye* [2007]. They showed that the Aanderaa DCS has a tendency to underestimate the current strength. For the KESS instruments, the speeds were multiplied by a factor of 1.1 to reduce this bias.

Finally the corrected speed and directions were converted back into u (positive east) and v (positive north) velocities and lowpass filtered. Filtering was done using a fourth order Butterworth filter with a 3 day cutoff, run forward and backward to eliminate phase shifting. The filtered data were then subsampled at half day intervals.

2.6 Special Cases

2.6.1 Site C2 SN 68

After the release command was sent to IES SN 68 on the recovery cruise in June 2006, the instrument did not break free of the anchor and could not be recovered. Daily-averaged travel time, pressure and current measurements were collected from the instrument, still on the seafloor, via pulse-delay telemetry to the ship (temperature data are not telemetered).

The daily pressures were dedrifted and leveled following the same procedures as the other KESS instruments. It was not necessary to run the response analysis program to remove the tides, because the daily values were obtained by processing the measured pressures with a Godin filter [*Godin*, 2007].

The travel time, pressure and current velocities were lowpass filtered using the same filtering parameters applied to the other KESS records.

2.6.2 Site E5 SN 143

Special processing was necessary for Site E5 (SN 143) because of jumps in both the pressure and travel time data. The pressure record at E5 exhibited two large jumps to deeper pressures of roughly 6 and 3 dbar, respectively, as well as several smaller jumps. Corresponding changes in the travel time measurements were also observed. It is surmised that the instrument slid down the flank of a nearby seamount on both occasions. Since pressure jumps are easier to identify than τ jumps, we identified the timing and magnitude of the jumps with the pressure record. The travel time record was adjusted by scaling the pressure adjustments from decibars to seconds.

The original pressure record was processed through the initial detiding step using the standard processing codes (Step 3, Figure 4). In the KESS region, the tidal signal is the dominant ocean signal in the pressure records. With the tides removed, the residual pressures were expected to vary by a negligible amount during the short time interval of each jump. This assumption permitted us to set all points within each jump to equal the detided measurement just prior to the jump and adjust the remainder of the pressure record accordingly. The tidal signal was restored to the pressures after the adjustments were made. Ten-day segments of the pressure records near the jumps are shown in Figure 9, before (row 1) and after (row 2) the correction process.

The travel time jumps were fixed by scaling the pressure jumps using $\tau = 2(\frac{\delta p}{1.01})c^{-1}$, where c is the sound speed near the bottom and $\frac{\delta p}{1.01}$ expresses the pressure jump as a depth change. The adjustments were applied to the individual echo returns measured every 10 minutes. The travel time records are also shown in Figure 9, before (row 3) and after (row 4) the corrections.

Strong velocities coincided with the pressure jumps. However, there was no evidence of offsets in the velocity records. No discernable jumps were evident in the measured temperatures. Thus,

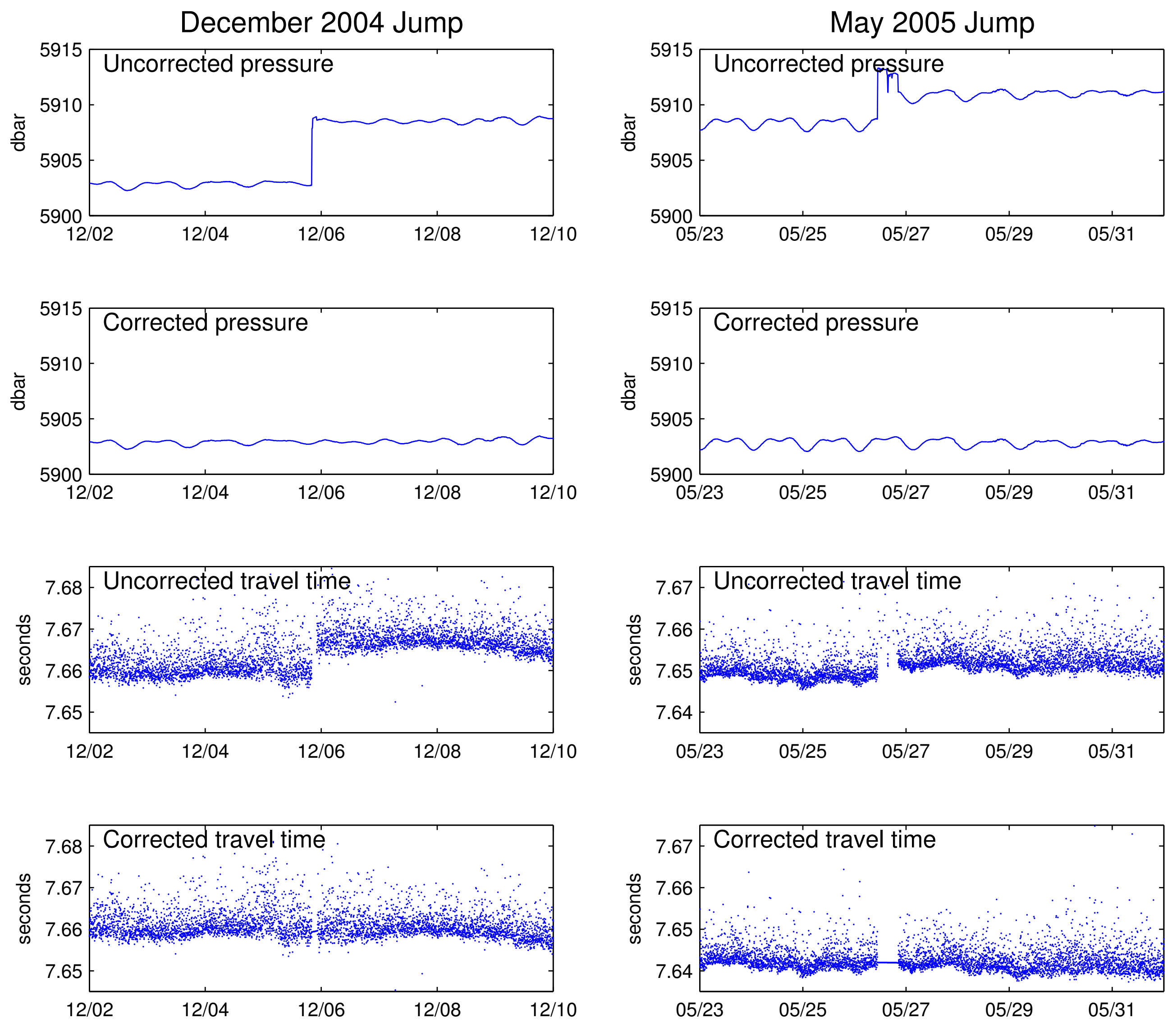


Figure 9: Ten-day segments of the pressure and travel time records before and after corrections for jumps in December 2004 (left) and May 2005 (right) for Site E5.

velocity and temperature records were not modified.

After the jumps were removed from the pressure and travel time records, they were processed in the same manner as all the other sites using the standard processing package.

2.6.3 Site S1 SN 101

When IES SN 101 was recovered in June 2005, the travel time data file recorded on the memory card was corrupt and the hourly burst measurements could not be downloaded for processing. However, because the instrument was prepared with telemetry mode enabled, it was possible to retrieve daily-averaged travel times from the stored telemetry data file.

To insure consistency, the daily travel times were lowpass filtered using the same filtering parameters as the measurements at the other sites. Unfortunately, no calibration CTDs were available for this instrument, so it was not possible to convert the measured travel times (τ_m) to τ_{index} as described in Section 2.2.

2.6.4 Special processing of DCS temperatures

The DCS temperature records from sites D5, D6, G5, H2, and S1 exhibited large fluctuations (Figure 10). For 4 of the 5 records, the largest fluctuations occurred within the first 100 days after deployment, after which the temperature variations returned to normal values. For the remaining site (S1), the variability remained high throughout the whole record.

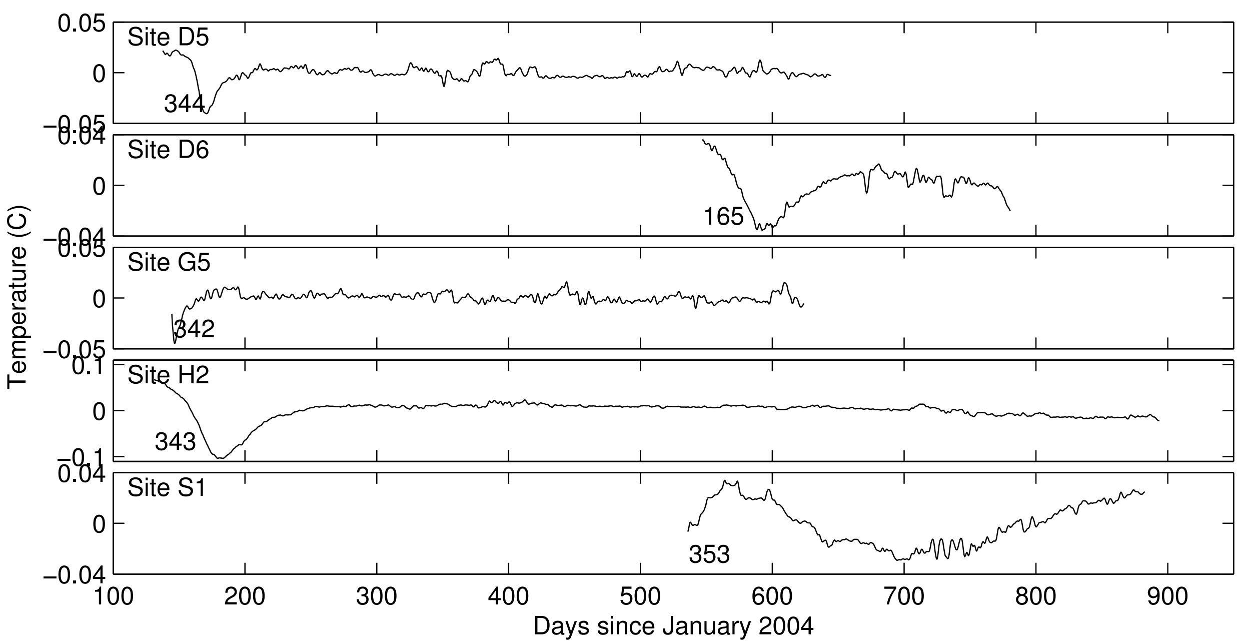


Figure 10: Time series of lowpass filtered DCS temperature variations for Sites D5, D6, G5, H2 and S1. DCS SN is shown below the beginning of each time series.

The temperatures recorded by these five instruments differ greatly from the other temperatures observed in the array. The DCS temperature records shown in Figure 10 exhibit ranges of 0.06–0.17°C, whereas those measured by the Paroscientific sensors inside the corresponding CPIES had ranges of only 0.01–0.04°C. Additionally, the temperatures measured by both the Paroscientific and DCS sensors at the remaining CPIES sites exhibited ranges similar to these latter values (see Figures 23-26).

Natural variability in the deep ocean in the KESS region cannot account for these extreme fluctuations. Therefore, they are believed to have resulted from instrumental problems. Examination of SN 353 (S1) showed that the connector pins had been damaged by salt water.

The early portions of the DCS temperature records at sites D5, D6, G5, and H2 were excised and the record at S1 was completely discarded. The minimum and maximum temperatures of the retained portions are listed in Table 15; these are comparable to those listed for the other DCS records.

3 Travel Time Records

Table 8 lists the mean, minimum, maximum and standard deviation of the hourly τ values as well as the start and end time of each τ record. Lowpass filtered τ records are shown in Figures 11-14. IES serial number is shown below the beginning of each time series. For sites with multiple instruments, the second and third time series are plotted in red and green respectively.

The values calculated by Equation 14 for C_{IES} (Section 2.2) are listed in Table 5. C_{IES} is used to convert τ to τ_{0-4000}. Only the best data at a particular site are converted to τ_{index}. Therefore, there are no C_{IES} values for C3 (SN 63), F3 (SN 147), and N1 (SN 45). There was no calibration CTD associated with S1 (SN 101) and subsequently a value of C_{IES} could not be calculated for that site.

Table 8

Site	IES SN	Start Date	Start Time	End Date	End Time	Mean (s)	Min (s)	Max (s)	STD (s)
A2	145	05/27/04	4:25:55	06/20/06	19:25:55	7.513	7.495	7.521	4.25E-03
B1	151	05/18/04	6:25:47	04/04/06	22:25:47	7.321	7.299	7.333	4.95E-03
B2	152	05/17/04	23:25:29	03/10/06	22:25:29	7.177	7.156	7.186	4.70E-03
B3	148	05/17/04	15:25:51	06/20/06	1:25:51	7.414	7.400	7.423	3.85E-03
B4	164	05/17/04	7:25:48	12/02/05	10:25:48	7.471	7.458	7.481	4.10E-03
B5	167	05/26/04	1:25:52	12/06/05	22:25:52	7.592	7.579	7.602	4.50E-03
C1	153	05/18/04	13:25:50	12/10/05	22:25:50	7.457	7.434	7.472	8.65E-03
C2	131	05/12/04	8:25:29	03/04/05	22:25:29	7.541	7.519	7.554	9.63E-03
C2	68	07/15/05	12:00:00	06/16/06	12:00:00	7.552	7.543	7.566	4.89E-03
C3	124	05/12/04	13:26:05	06/19/06	20:26:05	7.339	7.317	7.349	5.48E-03
C3a	63	07/11/05	12:30:34	06/19/06	16:30:34	7.336	7.326	7.346	3.36E-03
C4	144	05/16/04	23:25:53	05/02/06	22:25:53	7.430	7.416	7.438	3.49E-03
C5	171	05/25/04	7:25:29	11/21/04	21:25:29	7.669	7.664	7.673	1.36E-03
C5a	116	06/28/05	18:25:42	06/23/06	8:25:42	7.667	7.654	7.676	4.33E-03
C6	173	05/25/04	15:26:06	06/22/06	5:26:06	7.727	7.711	7.738	5.88E-03
D1	157	05/18/04	23:26:31	12/18/05	22:26:31	7.560	7.547	7.577	5.60E-03
D2	122	05/12/04	1:25:29	03/25/05	22:25:29	7.630	7.616	7.655	9.03E-03
D2	155	07/14/05	18:25:45	06/17/06	0:25:45	7.641	7.626	7.655	5.71E-03
D3	104	06/24/05	16:30:43	01/18/06	23:30:43	7.718	7.708	7.728	3.84E-03
D4	105	05/16/04	6:26:03	06/24/06	17:26:03	7.944	7.925	7.957	7.28E-03
D5	111	05/16/04	11:25:52	10/06/05	22:25:52	7.691	7.672	7.702	5.95E-03
D6	155	05/25/04	0:25:29	06/16/05	22:25:29	7.863	7.848	7.874	6.18E-03
D6	101	06/29/05	3:25:29	02/19/06	22:25:29	7.865	7.855	7.879	5.59E-03
E1	161	05/19/04	5:25:29	06/16/05	22:25:29	7.031	7.023	7.039	3.26E-03
E1	122	07/15/05	15:25:41	06/16/06	11:25:41	7.036	7.028	7.049	4.09E-03
E2	162	05/19/04	11:25:49	06/15/06	23:25:49	7.554	7.540	7.579	7.16E-03
E3	121	05/11/04	11:26:07	06/15/06	11:26:07	7.720	7.704	7.739	7.62E-03
E4	137	05/13/04	6:25:29	06/24/05	22:25:29	7.868	7.859	7.887	5.42E-03
E4	137	07/12/05	10:30:41	06/25/06	2:30:41	7.871	7.857	7.883	5.29E-03
E4a	68	06/25/05	7:25:29	07/12/05	6:25:29	7.862	7.859	7.866	1.23E-03

Continued on next page

Table 8 – continued from previous page

Site	IES SN	Start Date	Start Time	End Date	End Time	Mean (s)	Min (s)	Max (s)	STD (s)
E5	143	05/15/04	23:25:29	08/20/05	23:25:29	7.650	7.633	7.665	7.59E-03
E6	156	05/20/04	6:31:00	03/09/06	22:31:00	7.876	7.863	7.893	7.24E-03
E7	170	05/24/04	12:30:29	05/09/05	22:30:29	8.089	8.082	8.109	5.17E-03
E7	110	05/20/04	12:25:29	09/17/05	22:25:29	8.088	8.080	8.108	5.18E-03
E7a	170	07/07/05	1:30:42	06/10/06	23:30:42	8.089	8.078	8.106	6.56E-03
F1	114	05/30/04	0:25:29	07/02/05	22:25:29	7.176	7.164	7.193	8.21E-03
F2	136	05/11/04	4:25:29	04/01/05	22:25:29	7.643	7.633	7.665	8.99E-03
F2	102	06/26/05	0:25:29	11/04/05	22:25:29	7.642	7.637	7.653	3.09E-03
F3	147	05/16/04	16:26:05	06/25/06	11:26:05	7.685	7.670	7.710	8.79E-03
F3a	134	05/15/04	9:30:29	03/23/06	22:30:29	7.674	7.662	7.698	7.09E-03
F4	142	05/15/04	2:25:43	06/09/05	9:25:43	7.745	7.736	7.766	6.30E-03
F5	158	05/23/04	16:25:29	06/10/06	0:25:29	7.961	7.947	7.981	8.82E-03
F6	174	05/24/04	3:26:00	06/11/06	12:26:00	8.166	8.153	8.189	8.51E-03
G1	115	05/29/04	15:25:50	03/02/06	22:25:50	7.311	7.302	7.331	7.25E-03
G2	119	05/10/04	15:25:29	02/21/06	22:25:29	7.605	7.597	7.621	4.91E-03
G3	138	05/14/04	1:25:29	06/26/05	22:25:29	7.600	7.588	7.623	6.69E-03
G4	109	05/14/04	14:25:45	09/23/05	22:25:45	7.837	7.826	7.864	6.35E-03
G5	149	05/23/04	6:25:29	09/16/05	22:25:29	8.215	8.205	8.238	7.49E-03
G6	107	05/21/04	22:25:29	04/17/05	22:25:29	8.297	8.288	8.318	6.29E-03
H2	118	05/09/04	14:26:06	06/13/06	23:26:06	7.469	7.461	7.492	5.56E-03
H3	112	04/29/04	19:25:29	11/11/05	23:25:29	7.718	7.711	7.730	2.66E-03
H4	132	05/14/04	7:25:29	08/31/05	22:25:29	7.885	7.878	7.891	2.35E-03
H5	168	05/23/04	0:25:39	10/20/05	22:25:39	7.950	7.944	7.966	3.01E-03
H6	166	05/22/04	9:25:29	06/12/06	7:25:29	7.579	7.571	7.590	3.28E-03
I1	163	05/29/04	2:25:29	06/03/06	5:25:29	7.735	7.726	7.745	2.56E-03
N1	160	05/26/04	15:26:08	06/21/06	6:26:08	7.558	7.542	7.569	3.42E-03
N1a	45	07/04/05	17:30:29	07/22/05	22:30:29	7.560	7.554	7.565	2.21E-03
S1	101	04/28/04	12:00:00	03/07/05	12:00:00	7.831	7.826	7.842	2.32E-03
S1	36	06/18/05	22:30:24	06/02/06	12:30:24	7.839	7.834	7.843	1.68E-03
S2	102	04/27/04	4:25:29	06/19/05	9:25:29	7.427	7.420	7.432	1.96E-03
S2	43	06/19/05	12:30:38	06/02/06	23:30:38	7.435	7.430	7.444	2.21E-03

Table 8: Statistics for the hourly τ records. Times are UT.

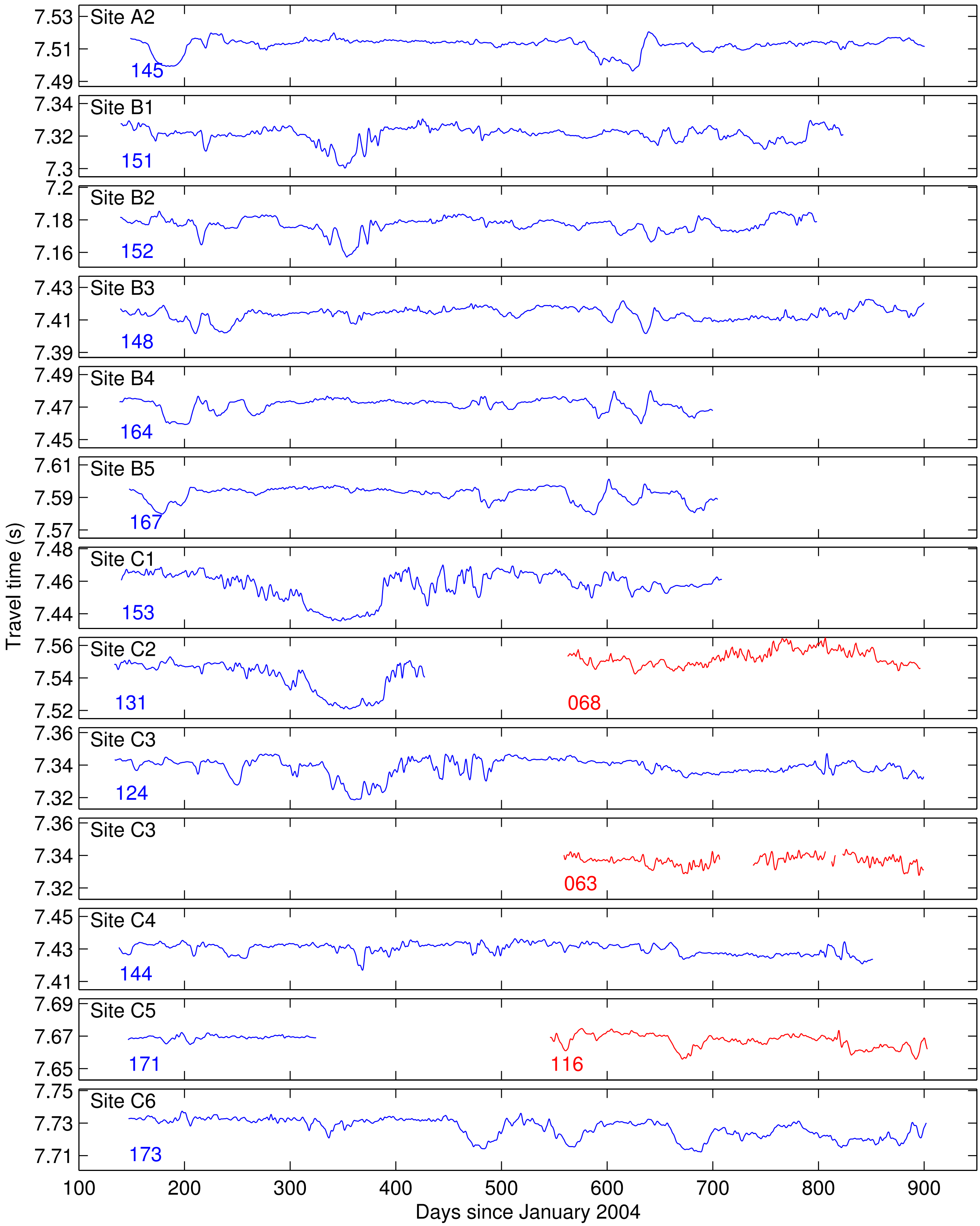


Figure 11: Time series of 72 hr lowpass filtered travel times (lines A-C). IES SN is shown below the beginning of each time series.

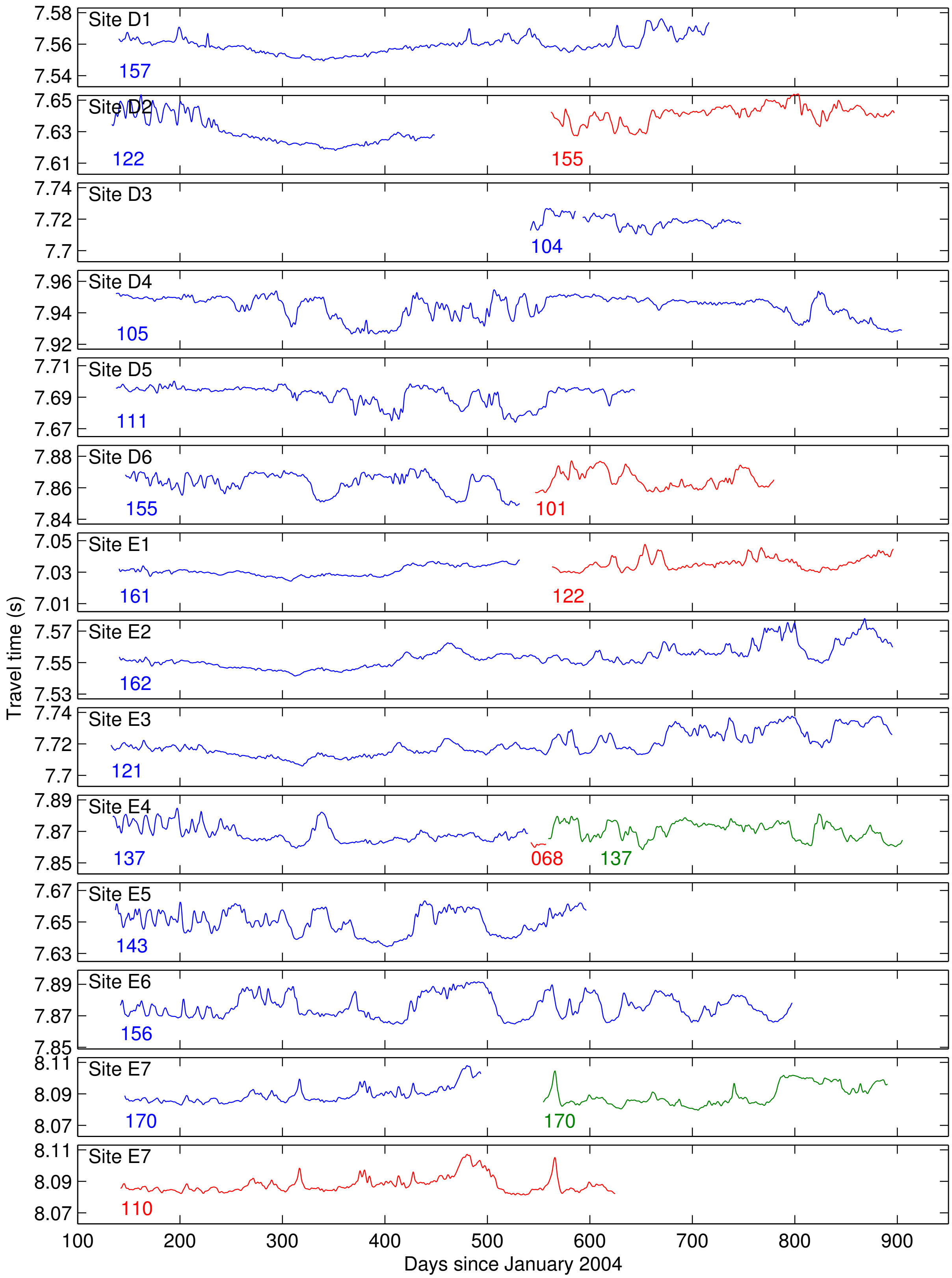


Figure 12: Time series of 72 hr lowpass filtered travel times (lines D-E). IES SN is shown below the beginning of each time series.

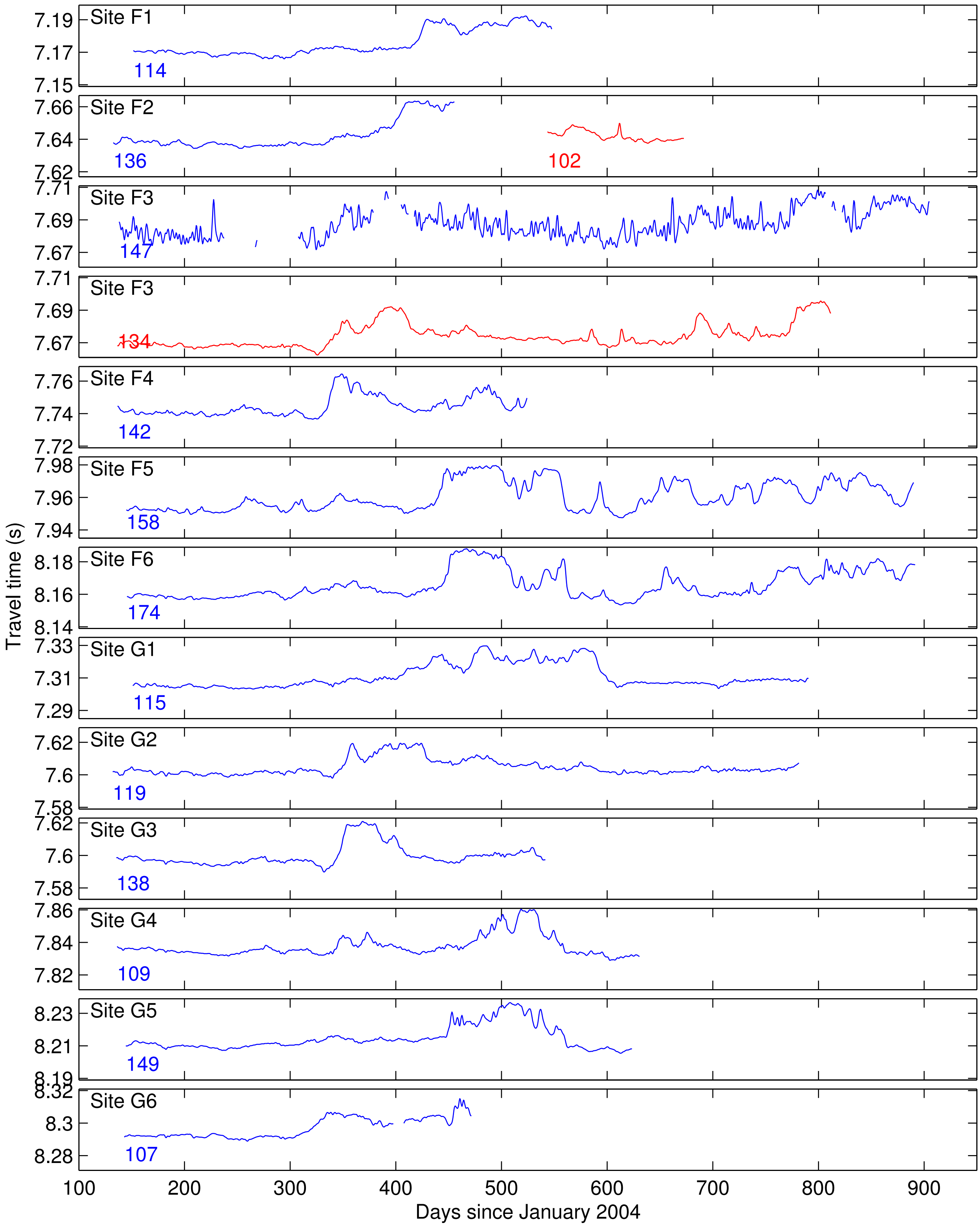


Figure 13: Time series of 72 hr lowpass filtered travel times (lines F-G). IES SN is shown below the beginning of each time series.

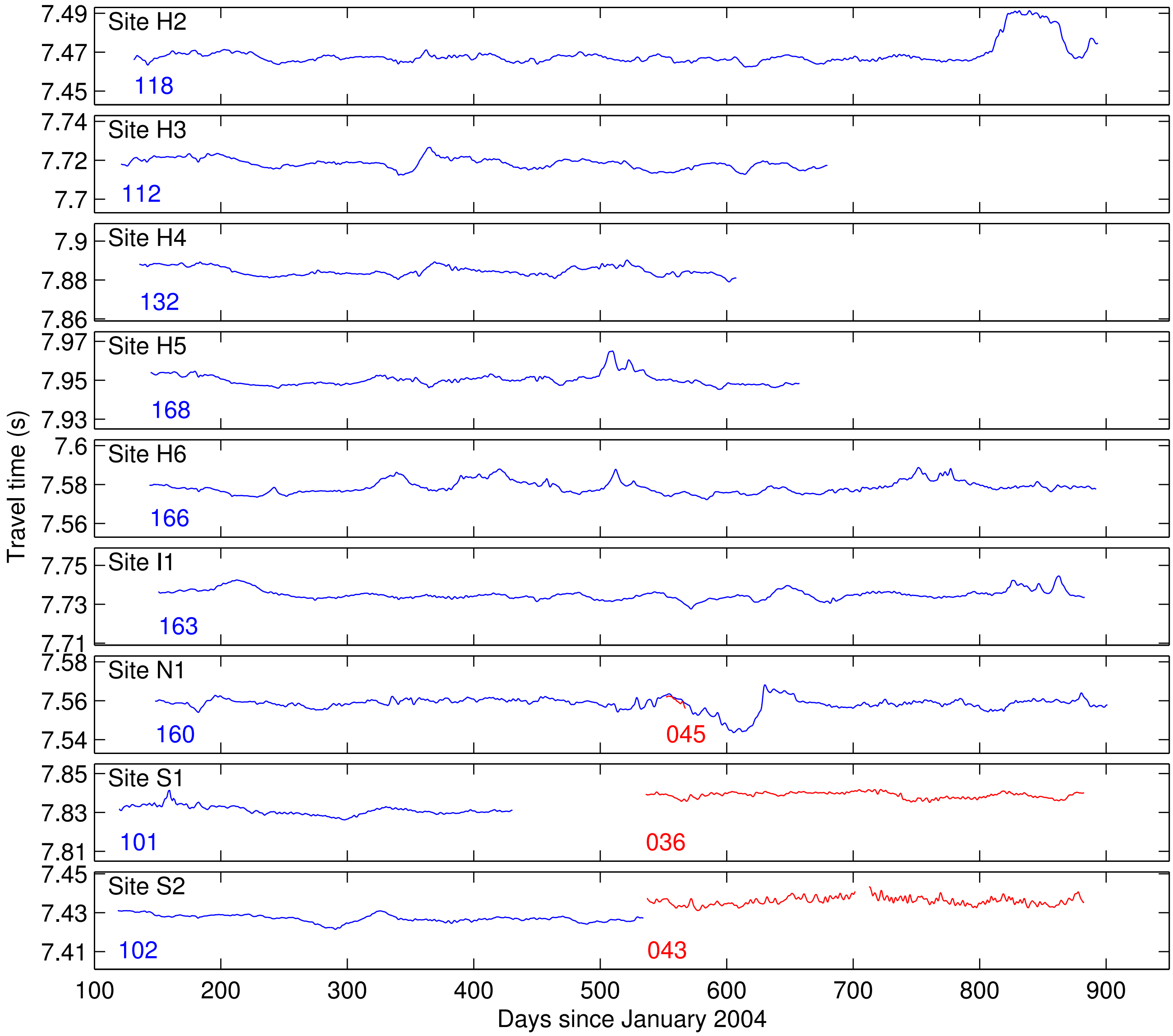


Figure 14: Time series of 72 hr lowpass filtered travel times (lines H-S). IES SN is shown below the beginning of each time series.

4 Pressure Records

Pressure records with the fitted (as described in Section 2.3.4) drift curves superimposed (shown in black) are plotted in Figures 15-18. The Paroscientific pressure sensor serial number is shown below the beginning of the time series for each instrument. For sites with multiple instruments, the second and third pressure time series are plotted in red and green respectively.

Table 9 lists the drift coefficients (A, B, C and D of Equation 23) found by the method described in Section 2.3.4. Also listed are the minimum and maximum drift for each instrument.

Table 10 lists the amplitudes and phases of the diurnal and semi-diurnal tidal constituents removed from the KESS records after dedrifting/leveling. RESPO used 3 time lags for all sites in detiding. There are no tidal constituents in Table 10 for Site C2 SN 68 for which only telemetry data were retrieved. Data that is telemetered has already been detided within the instrument using a Godin filter.

Table 11 lists the statistics for the hourly pressure records for each site. The minimum and maximum pressures were calculated after removing the mean from the records since the ranges are small relative to the bottom depth. Lowpass filtered pressure records which have means, tides and drifts removed are shown in Figures 19-22. The Paroscientific pressure sensor serial number is shown below the beginning of the time series for each instrument. For sites with multiple instruments, the second and third pressure time series are plotted in red and green respectively.

Table 9

Site	IES SN	Paros SN	Drift Coefficients				minimum drift	maximum drift
			A	B	C	D		
A2	145	91869	0.00000	0.00000	0.00068	-0.27495	-0.288	0.224
B1	151	91512	0.03614	-0.02774	-0.00032	0.10768	-0.100	0.197
B2	152	91498	0.04407	-0.03109	-0.00010	-0.00331	-0.066	0.108
B3	148	92040	0.07080	-0.02976	0.00001	-0.02678	-0.024	0.141
B4	164	91504	0.11198	-0.01185	-0.00010	-0.02628	-0.080	0.136
B5	167	91511	0.13042	-0.00857	-0.00005	-0.04574	-0.070	0.111
C1	153	91858	0.03000	-0.03991	0.00129	-0.32181	-0.292	0.376
C2	131	91856	0.00000	0.00000	-0.00015	0.02448	-0.015	0.030
C2	68	96931	0.35290	-0.00826	0.00044	-0.20509	-0.052	0.150
C3	124	91136	0.98419	-0.00145	0.00071	-0.89855	-0.069	0.112
C3a	63	96926	0.32000	-0.01154	0.00021	-0.14551	-0.075	0.175
C4	144	91525	0.24584	-0.00406	0.00014	-0.17038	-0.067	0.103
C5	171	92915	0.05000	-0.06082	-0.00045	-0.02929	-0.101	0.165
C5a	116	96850	0.22540	-0.05057	-0.00068	0.06684	-0.179	0.295
C6	173	91506	0.24471	-0.00596	-0.00002	-0.07066	-0.084	0.207
D1	157	92972	0.17499	-0.01405	-0.00016	0.00391	-0.086	0.267
D2	122	91857	0.10089	-0.01752	-0.00021	-0.02439	-0.084	0.169
D2	155	91520	0.04000	-0.09000	0.00006	-0.03276	-0.029	0.009
D3	104	97058	0.14873	-0.04404	-0.00100	0.06801	-0.139	0.220
D4	105	92911	0.17226	-0.00983	0.00006	-0.05713	-0.032	0.173
D5	111	91510	7.80206	-0.00052	0.00326	-7.71887	-0.086	0.109

Continued on next page

Table 9 – continued from previous page

Site	IES SN	Paros SN	Drift Coefficients A	B	C	D	minimum drift	maximum drift
D6	155	91520	-0.03460	-0.03408	-0.00034	0.03824	-0.086	0.016
D6	101	96932	0.18271	-0.10013	-0.00064	0.04414	-0.107	0.230
E1	161	91860	0.09680	-0.02137	0.00013	-0.05677	-0.034	0.114
E1	122	91857	0.00000	0.00000	-0.00002	-0.01935	-0.025	-0.019
E2	162	91866	0.13550	-0.02032	0.00005	-0.05939	-0.048	0.176
E3	121	90551	0.08783	-0.01782	-0.00014	0.01796	-0.085	0.188
E4	137	92910	0.15359	-0.01240	-0.00040	0.02835	-0.120	0.274
E4	137	92910	0.07861	-0.02466	-0.00038	0.06257	-0.069	0.142
E4a	68	96931	0.00000	0.00000	-0.00900	0.00117	-0.141	0.001
E5	143	91135	0.11000	-0.02653	0.00000	-0.02062	-0.022	0.229
E6	156	92909	0.26750	-0.00732	-0.00020	-0.04015	-0.164	0.290
E7	170	91521	0.01000	-0.10000	-0.00056	0.06676	-0.118	0.172
E7	110	91854	5.95063	-0.00082	0.00422	-5.95029	-0.058	0.067
E7a	170	91521	0.00000	0.00000	-0.00057	0.07176	-0.120	0.072
F1	114	91519	0.23007	-0.00523	0.00058	-0.25052	-0.058	0.003
F2	136	91526	0.19615	-0.00856	0.00009	-0.13832	-0.096	0.125
F2	102	92035	1.12103	-0.00552	0.00404	-1.14120	-0.097	-0.019
F3	147	91518	0.12275	-0.01731	-0.00020	0.03319	-0.113	0.258
F3a	134	91863	0.11600	-0.01731	0.00060	-0.22389	-0.148	0.160
F4	142	92964	0.19000	-0.01464	-0.00035	-0.01056	-0.135	0.302
F5	158	92966	0.23205	-0.00736	-0.00032	0.06162	-0.172	0.344
F6	174	92968	0.17998	-0.01972	-0.00031	0.11907	-0.105	0.408
G1	115	90776	0.00000	0.00000	0.00009	-0.04873	-0.050	0.005
G2	119	91144	0.00000	0.00000	0.00018	-0.06717	-0.074	0.043
G3	138	92034	0.15853	-0.01110	0.00008	-0.06810	-0.039	0.158
G4	109	91523	0.08000	-0.02833	-0.00050	0.10823	-0.126	0.324
G5	149	91500	0.09700	-0.01046	-0.00015	0.05313	-0.016	0.180
G6	107	91509	0.00000	0.00000	-0.00075	0.14655	-0.084	0.165
H2	118	92036	0.11329	-0.01167	0.00002	-0.03531	-0.025	0.139
H3	112	91502	0.04500	-0.01727	-0.00020	0.03179	-0.068	0.143
H4	132	91508	0.29855	-0.00442	0.00044	-0.23348	-0.026	0.097
H5	168	91868	0.12947	-0.00969	0.00129	-0.33191	-0.202	0.301
H6	166	92042	0.03696	-0.00519	0.00003	-0.03040	-0.015	0.011
I1	163	92962	0.25000	-0.01772	-0.00023	0.04699	-0.118	0.394
N1	160	91524	0.13911	-0.01150	-0.00032	0.06867	-0.167	0.251
N1a	45	96928	0.00000	0.00000	-0.00607	0.03621	-0.070	0.037
S1	101	91872	6.48995	-0.00141	0.00686	-6.38159	-0.118	0.242
S1	36	96841	0.21191	-0.06114	-0.00097	0.11005	-0.229	0.323
S2	102	92035	0.62032	-0.00351	0.00143	-0.62622	-0.047	0.071
S2	43	97059	0.21800	-0.05044	-0.00084	0.10125	-0.191	0.325

Table 9: IES serial number, Paroscientific pressure sensor serial number, coefficients for drift Equation 23 and maximum and minimum drift (in dbars).

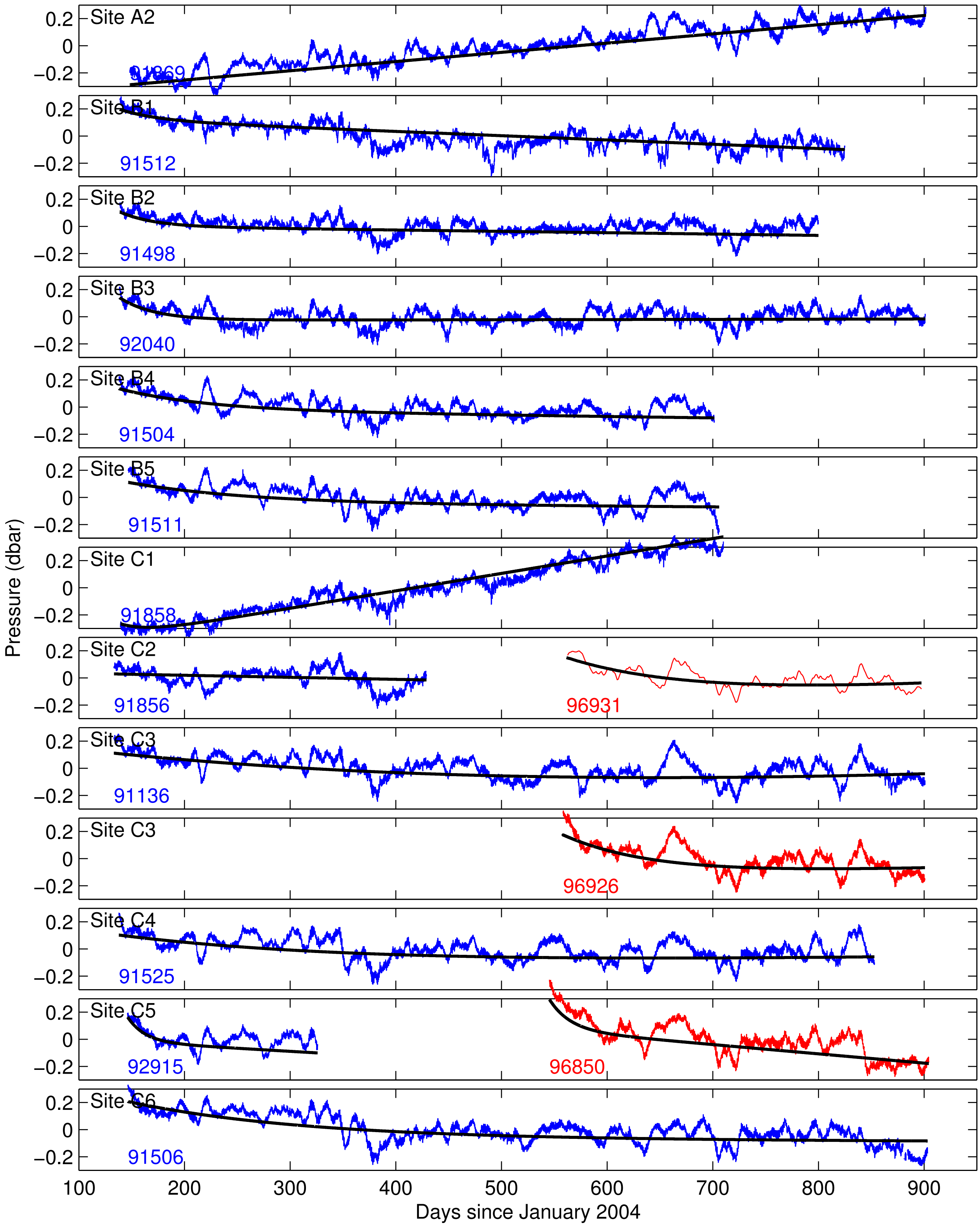


Figure 15: Time series of hourly pressure with drift curves superimposed (lines A-C). The Paroscientific pressure sensor SN is shown below the beginning of the time series.

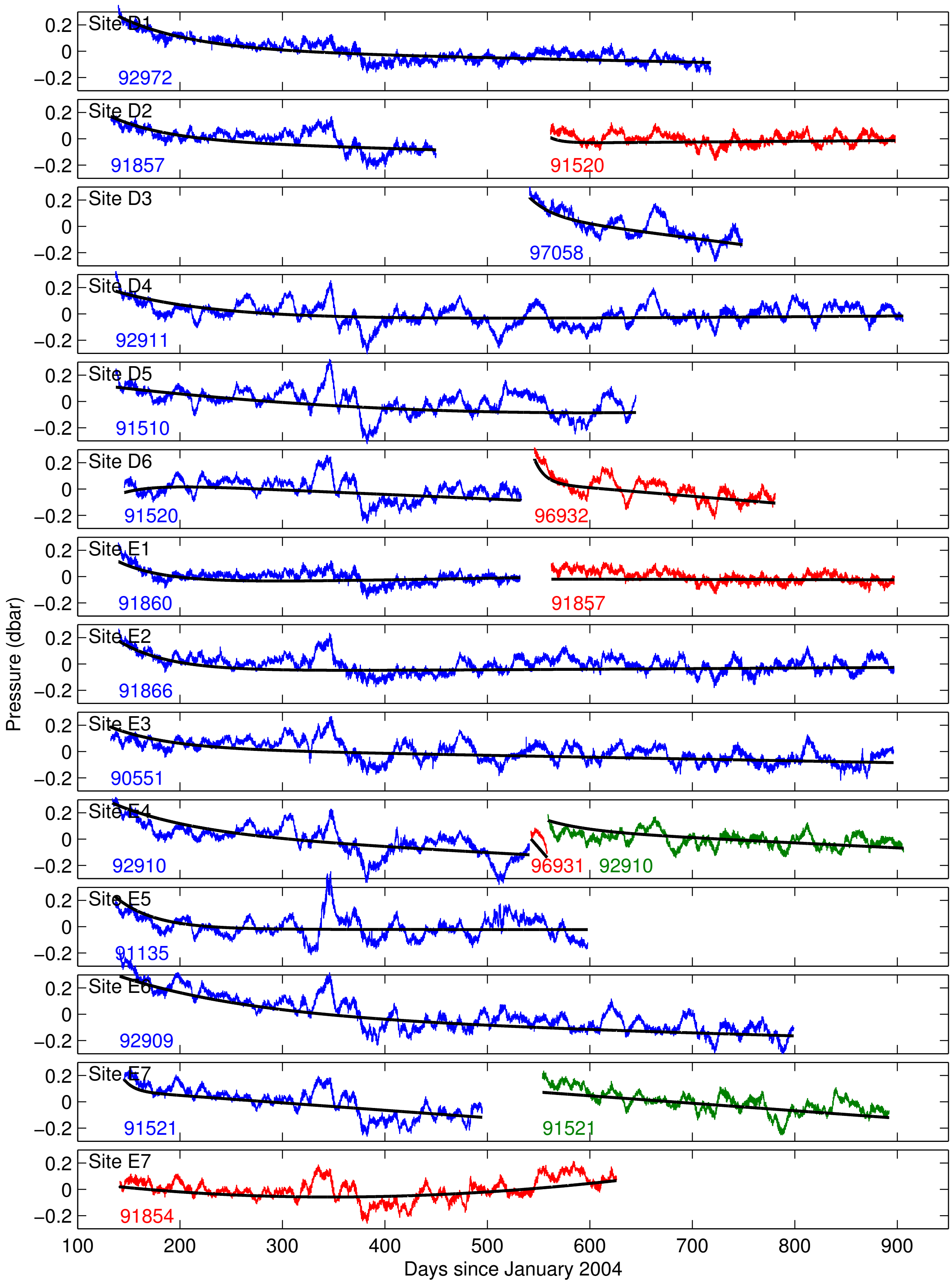


Figure 16: Time series of hourly pressure with drift curves superimposed (lines D-E). The Paroscientific pressure sensor SN is shown below the beginning of the time series.

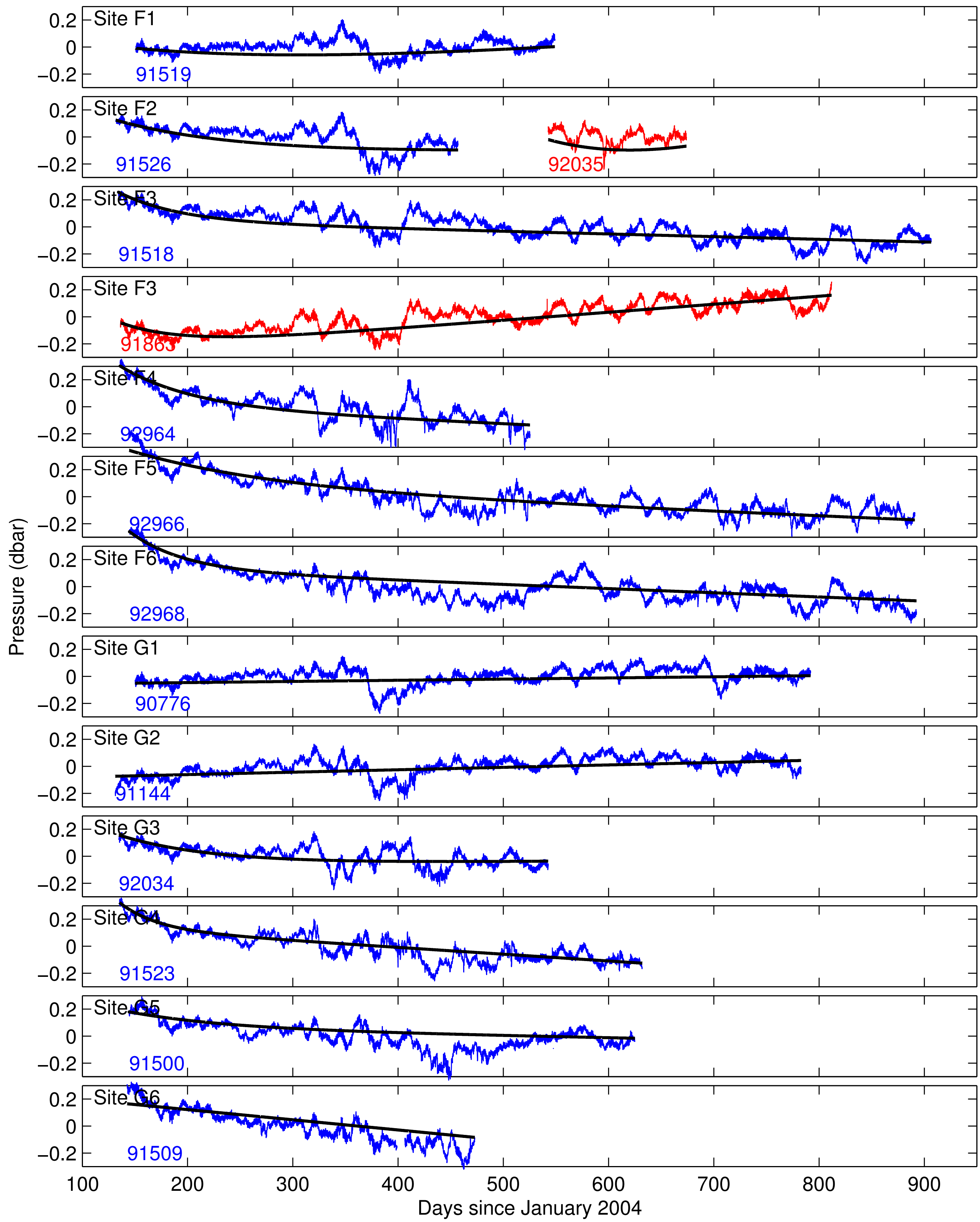


Figure 17: Time series of hourly pressure with drift curves superimposed (lines F-G). The Paroscientific pressure sensor SN is shown below the beginning of the time series.

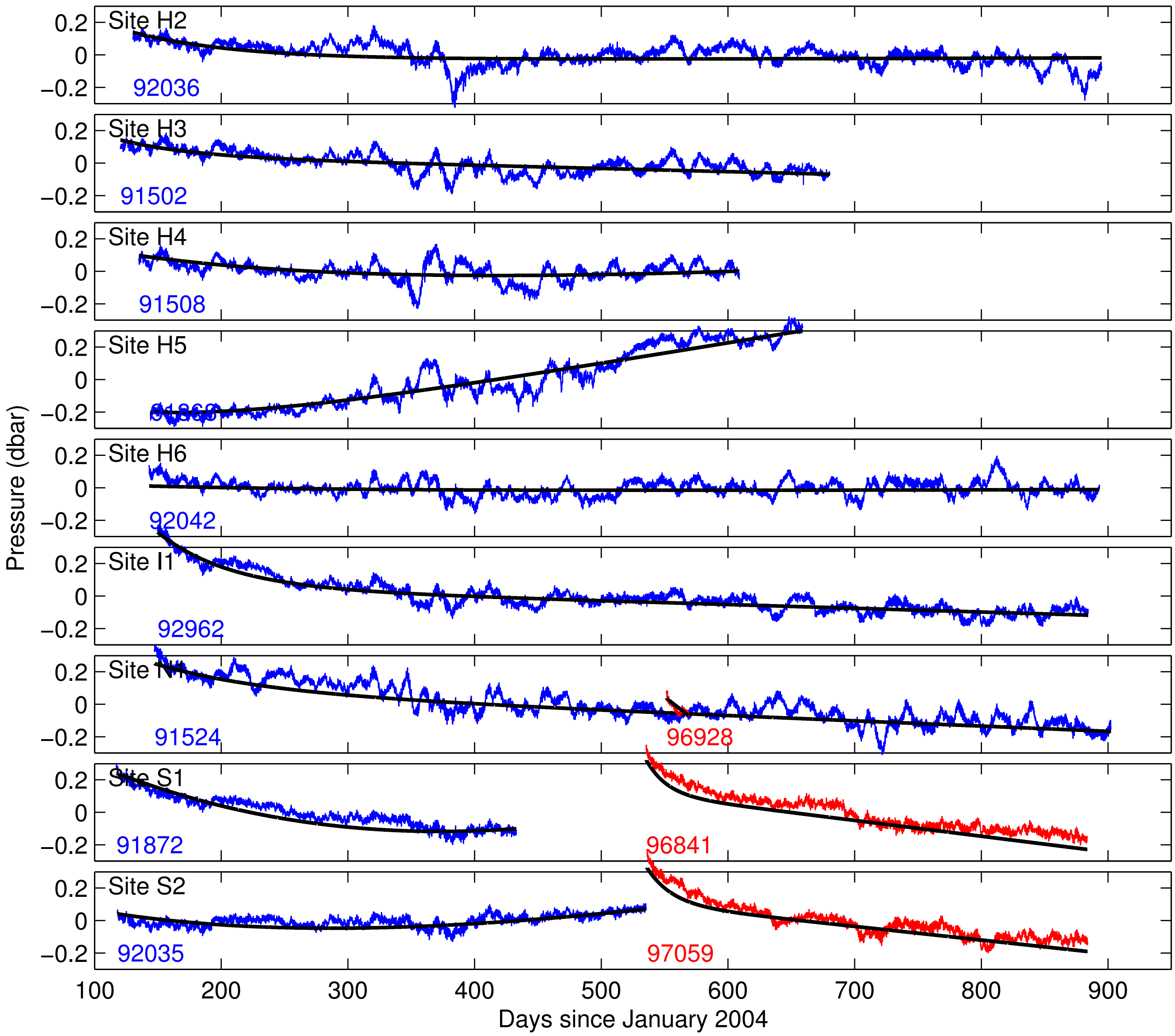


Figure 18: Time series of hourly pressure with drift curves superimposed (lines H-S). The Paroscientific pressure sensor SN is shown below the beginning of the time series.

Table 10

Site SN	Amp Phase	O1	K1	Q1	P1	M2	K2	N2	S2
A2	H(cm)	16.56	20.21	3.26	6.77	21.63	2.94	2.20	10.84
145	G(deg)	4.85	23.74	358.22	22.20	182.32	232.34	164.74	226.43
B1	H(cm)	17.33	21.27	3.42	7.12	24.95	3.33	2.92	12.29
151	G(deg)	9.72	28.18	3.31	26.68	192.30	236.12	182.17	230.94
B2	H(cm)	16.86	20.67	3.36	6.91	23.53	3.20	2.62	11.76
152	G(deg)	8.85	27.38	2.57	25.89	190.53	236.05	180.26	230.65
B3	H(cm)	16.70	20.42	3.30	6.84	22.60	3.07	2.42	11.32
148	G(deg)	7.65	26.55	0.99	25.02	188.26	235.05	175.37	229.50
B4	H(cm)	16.31	19.88	3.23	6.66	21.49	2.97	2.16	10.90
164	G(deg)	6.26	25.26	359.61	23.72	185.60	234.30	171.96	228.48
B5	H(cm)	16.04	19.53	3.18	6.54	20.45	2.85	1.99	10.44
167	G(deg)	5.01	24.23	358.38	22.67	183.00	233.64	167.43	227.61
C1	H(cm)	17.15	21.11	3.41	7.06	25.12	3.35	2.98	12.35
153	G(deg)	11.05	29.64	4.58	28.15	196.94	239.41	189.98	234.30
C2	H(cm)	16.72	20.45	3.31	6.85	23.50	3.22	2.71	11.78
131	G(deg)	10.26	28.91	3.38	27.44	195.31	239.68	190.36	234.32
C3	H(cm)	16.38	20.05	3.24	6.71	22.24	3.07	2.42	11.27
124	G(deg)	9.20	28.17	2.58	26.63	192.79	237.97	183.90	232.58
C3a	H(cm)	16.35	20.11	3.22	6.73	22.23	3.07	2.39	11.31
063	G(deg)	9.02	27.91	2.41	26.38	192.52	237.40	180.21	232.13
C4	H(cm)	16.03	19.66	3.16	6.58	21.10	2.96	2.17	10.86
144	G(deg)	7.85	26.92	1.20	25.36	190.08	236.84	179.56	231.29
C5	H(cm)	15.79	19.17	3.11	6.43	20.47	2.86	2.00	10.48
171	G(deg)	6.41	25.89	359.16	24.34	186.33	235.79	177.14	229.78
C5a	H(cm)	15.76	19.37	3.09	6.48	20.32	2.87	1.97	10.58
116	G(deg)	6.42	25.56	359.91	23.98	186.67	235.44	168.04	229.78
C6	H(cm)	15.34	18.70	3.08	6.25	19.09	2.73	1.83	9.99
173	G(deg)	5.32	24.44	359.35	22.85	183.73	234.42	168.74	228.50

Continued on next page

Table 10 – continued from previous page

Site SN	Amp Phase	O1	K1	Q1	P1	M2	K2	N2	S2
D1	H(cm)	16.95	20.81	3.30	6.98	24.49	3.28	2.90	12.09
157	G(deg)	13.67	32.14	7.24	30.60	203.05	243.47	200.91	238.39
D2	H(cm)	16.61	20.38	3.28	6.82	23.53	3.27	2.82	11.95
122	G(deg)	12.13	31.02	5.43	29.51	199.72	242.81	197.31	237.65
D2	H(cm)	16.56	20.45	3.26	6.84	23.41	3.22	2.70	11.85
155	G(deg)	12.11	30.95	5.58	29.42	199.90	241.62	191.91	236.70
D3	H(cm)	16.26	20.04	3.23	6.70	22.66	3.16	2.53	11.59
104	G(deg)	10.88	29.52	5.14	27.95	196.63	240.87	189.02	235.65
D4	H(cm)	15.83	19.43	3.12	6.50	20.91	2.96	2.18	10.85
105	G(deg)	9.67	28.91	2.93	27.35	194.25	239.63	186.87	234.21
D5	H(cm)	15.44	18.86	3.06	6.31	19.72	2.85	1.97	10.40
111	G(deg)	8.29	27.71	1.42	26.15	191.08	238.53	184.23	232.88
D6	H(cm)	15.17	18.51	3.00	6.20	18.68	2.73	1.73	9.94
155	G(deg)	6.65	26.40	0.05	24.76	187.55	237.18	179.40	231.23
D6	H(cm)	15.19	18.63	3.00	6.23	19.12	2.81	1.76	10.29
101	G(deg)	6.78	25.58	0.56	24.02	187.46	237.25	171.37	231.50
E1	H(cm)	16.96	20.91	3.34	7.00	25.14	3.40	3.26	12.45
161	G(deg)	15.40	34.53	8.33	33.02	208.19	247.16	207.33	242.41
E1	H(cm)	16.83	20.85	3.31	6.97	24.88	3.38	3.11	12.44
122	G(deg)	15.39	34.29	8.56	32.78	208.24	246.66	203.71	242.09
E2	H(cm)	16.45	20.30	3.23	6.79	23.46	3.24	2.86	11.90
162	G(deg)	14.17	33.23	7.42	31.69	205.09	245.19	202.35	240.38
E3	H(cm)	15.96	19.60	3.16	6.56	21.79	3.04	2.46	11.16
121	G(deg)	12.96	32.04	6.33	30.50	202.40	244.07	200.54	238.94
E4	H(cm)	15.75	19.35	3.10	6.48	20.95	2.96	2.33	10.82
137	G(deg)	11.60	31.06	4.46	29.52	198.86	242.59	197.06	237.26
E4a	H(cm)	15.53	19.00	2.76	6.41	21.75	3.08	1.98	11.10
068	G(deg)	13.21	30.44	11.58	28.37	198.97	250.97	211.39	243.94
E4	H(cm)	15.59	19.25	3.06	6.44	20.76	2.96	2.20	10.86
137	G(deg)	11.44	30.67	4.81	29.09	198.91	242.33	191.16	237.20

Continued on next page

Table 10 – continued from previous page

Site SN	Amp Phase	O1	K1	Q1	P1	M2	K2	N2	S2
E5	H(cm)	15.30	18.71	3.03	6.26	19.59	2.86	2.06	10.39
143	G(deg)	10.26	29.71	3.42	28.14	195.77	241.64	193.43	236.15
E6	H(cm)	14.90	18.24	2.95	6.10	18.44	2.74	1.76	9.98
156	G(deg)	8.33	27.93	1.79	26.32	192.18	239.68	186.24	234.05
E7	H(cm)	14.67	17.93	2.89	6.00	17.59	2.65	1.60	9.62
170	G(deg)	7.16	27.05	0.33	25.41	188.63	237.67	182.26	231.88
E7	H(cm)	14.59	17.83	2.88	5.97	17.51	2.65	1.58	9.61
110	G(deg)	6.99	26.88	0.45	25.22	188.38	237.91	180.37	232.12
E7a	H(cm)	14.56	17.91	2.86	5.99	17.60	2.62	1.55	9.59
170	G(deg)	7.05	26.73	0.28	25.11	188.37	237.58	172.35	231.86
F1	H(cm)	16.35	20.17	3.23	6.75	23.56	3.27	3.11	11.95
114	G(deg)	16.86	36.20	9.68	34.68	212.01	250.33	214.39	245.63
F2	H(cm)	15.75	19.44	3.12	6.50	21.64	3.11	2.68	11.30
136	G(deg)	15.25	34.62	8.30	33.09	208.29	248.78	211.51	243.84
F2	H(cm)	15.78	19.53	3.11	6.53	22.41	3.19	2.63	11.68
102	G(deg)	14.76	34.29	7.83	32.73	207.15	247.44	204.51	242.65
F3	H(cm)	15.35	18.95	3.02	6.34	20.44	2.94	2.31	10.74
147	G(deg)	13.71	33.21	6.91	31.63	204.61	246.37	204.57	241.29
F3a	H(cm)	15.40	19.02	3.04	6.36	20.51	2.98	2.34	10.86
134	G(deg)	13.52	32.85	6.78	31.29	204.28	245.98	204.94	240.94
F4	H(cm)	15.10	18.52	2.97	6.20	19.39	2.82	2.10	10.27
142	G(deg)	12.35	32.11	5.28	30.51	201.19	244.21	202.20	238.94
F5	H(cm)	14.59	17.95	2.87	6.00	17.97	2.70	1.72	9.81
158	G(deg)	10.31	30.11	3.55	28.48	196.51	242.15	194.39	236.66
F6	H(cm)	14.27	17.54	2.81	5.87	17.08	2.59	1.54	9.43
174	G(deg)	9.28	29.40	2.44	27.75	193.84	241.49	188.90	235.82
G1	H(cm)	15.53	19.21	3.07	6.42	21.87	3.13	2.80	11.41
115	G(deg)	17.69	36.97	10.89	35.43	214.12	252.37	216.99	247.73
G2	H(cm)	15.19	18.80	2.99	6.29	20.37	2.98	2.48	10.83
119	G(deg)	16.12	35.50	9.43	33.92	210.17	249.77	213.97	244.94

Continued on next page

Table 10 – continued from previous page

Site SN	Amp Phase	O1	K1	Q1	P1	M2	K2	N2	S2
G3	H(cm)	14.71	18.17	2.91	6.07	18.97	2.81	2.22	10.18
138	G(deg)	14.28	34.24	7.35	32.63	206.82	248.37	210.85	243.33
G4	H(cm)	14.36	17.72	2.85	5.92	17.81	2.70	1.90	9.77
109	G(deg)	12.77	32.81	5.36	31.25	202.52	246.03	206.90	240.74
G5	H(cm)	14.16	17.41	2.80	5.82	16.98	2.62	1.66	9.50
149	G(deg)	11.27	31.52	4.23	29.88	198.00	243.36	200.55	237.92
G6	H(cm)	13.15	16.41	2.32	5.55	15.60	2.45	1.09	8.90
107	G(deg)	9.32	30.18	359.39	28.44	193.70	243.10	187.19	237.09
H2	H(cm)	14.82	18.45	2.92	6.16	20.19	2.90	2.62	10.56
118	G(deg)	18.51	38.27	11.78	36.67	217.63	254.94	222.74	250.32
H3	H(cm)	14.38	17.83	2.84	5.95	18.56	2.75	2.30	9.97
112	G(deg)	16.30	36.48	9.75	34.81	212.14	250.89	219.99	246.04
H4	H(cm)	14.25	17.63	2.80	5.90	17.70	2.69	2.02	9.72
132	G(deg)	15.08	35.24	8.02	33.60	208.39	249.84	215.91	244.73
H5	H(cm)	13.85	17.12	2.73	5.72	16.47	2.57	1.70	9.29
168	G(deg)	13.20	33.61	6.56	31.91	203.76	246.48	210.53	241.27
H6	H(cm)	13.51	16.72	2.65	5.59	15.53	2.42	1.39	8.77
166	G(deg)	11.40	31.96	4.46	30.25	198.64	244.62	201.43	239.03
I1	H(cm)	14.50	18.15	2.86	6.06	20.36	2.96	2.80	10.75
163	G(deg)	20.83	40.44	14.23	38.85	223.58	258.71	229.46	254.40
N1	H(cm)	16.83	20.50	3.32	6.87	21.80	2.94	2.22	10.85
160	G(deg)	3.56	22.38	356.93	20.84	179.25	230.40	158.01	224.38
N1a	H(cm)	16.88	20.35	3.43	6.82	22.62	3.37	2.74	12.18
045	G(deg)	4.13	22.06	355.16	20.96	179.07	236.66	153.03	231.02
S1	H(cm)	13.90	17.57	2.75	5.86	20.41	2.93	3.23	10.59
101	G(deg)	24.93	44.43	18.31	42.88	234.79	267.53	242.52	263.51
S1	H(cm)	13.83	17.73	2.73	5.90	20.38	2.91	2.99	10.59
036	G(deg)	24.80	44.45	17.79	42.94	234.51	266.79	240.87	262.78
S2	H(cm)	14.14	17.80	2.79	5.94	20.21	2.90	3.09	10.48
102	G(deg)	23.46	43.22	16.80	41.62	230.39	263.59	238.66	259.43

Continued on next page

Table 10 – continued from previous page

Site SN	Amp Phase	O1	K1	Q1	P1	M2	K2	N2	S2
S2	H(cm)	14.10	17.83	2.77	5.94	20.43	2.96	2.91	10.75
043	G(deg)	23.06	42.73	16.45	41.14	230.18	262.87	235.84	258.86

Table 10: Amplitudes(H) and phases(G) of the major diurnal and semi-diurnal tidal constituents. IES serial number is listed below the site designator.

Table 11

Site	IES SN	Start Date	Start Time	End Date	End Time	Mean (dbar)	Min (mbar)	Max (mbar)	STD (mbar)
A2	145	05/28/2004	03:26:25	06/20/2006	19:26:25	5788.30	-18.284	21.612	5.630
B1	151	05/18/2004	20:26:17	04/04/2006	22:26:17	5631.80	-30.162	15.064	5.941
B2	152	05/18/2004	14:25:59	03/10/2006	22:25:59	5516.54	-17.965	17.516	4.789
B3	148	05/18/2004	09:26:21	06/20/2006	01:26:21	5707.29	-19.043	17.856	5.566
B4	164	05/18/2004	00:26:18	12/02/2005	10:26:18	5754.07	-18.549	20.322	5.566
B5	167	05/26/2004	16:26:22	12/06/2005	22:26:22	5851.31	-21.529	19.470	6.317
C1	153	05/19/2004	07:26:20	12/10/2005	22:26:20	5745.72	-24.475	14.632	4.914
C2	131	05/13/2004	04:25:59	03/04/2005	22:25:59	5812.52	-21.741	18.957	6.553
C2	068	07/15/2005	12:00:00	06/16/2006	12:00:00	5815.49	-13.813	15.443	5.575
C3	124	05/13/2004	02:26:35	06/19/2006	20:26:35	5647.16	-21.829	27.574	7.019
C3a	063	07/12/2005	05:31:04	06/19/2006	18:31:04	5641.91	-18.521	26.657	7.481
C4	144	05/17/2004	19:26:23	05/02/2006	22:26:23	5720.17	-22.510	23.941	7.013
C5	171	05/26/2004	01:25:59	11/21/2004	22:25:59	5910.49	-13.976	18.539	5.845
C5a	116	06/29/2005	07:26:12	06/23/2006	11:26:12	5911.93	-17.861	22.132	7.568
C6	173	05/26/2004	10:26:36	06/22/2006	09:26:36	5961.43	-25.193	20.032	6.924
D1	157	05/19/2004	16:27:01	12/18/2005	22:27:01	5839.31	-14.350	13.875	4.218
D2	122	05/12/2004	11:25:59	03/25/2005	22:25:59	5893.92	-16.554	22.784	6.347
D2	155	07/15/2005	12:26:15	06/17/2006	03:26:15	5894.01	-14.171	15.154	4.350
D3	104	06/25/2005	02:31:13	01/18/2006	23:31:13	5951.99	-15.599	22.781	6.584
D4	105	05/17/2004	03:26:32	06/24/2006	19:26:32	6135.68	-28.045	27.132	7.415
D5	111	05/17/2004	06:26:22	10/06/2005	22:26:22	5929.93	-27.739	35.141	8.441
D6	155	05/25/2004	15:25:59	06/16/2005	21:25:59	6071.56	-22.632	27.859	7.412
D6	101	06/29/2005	20:25:59	02/19/2006	22:25:59	6076.86	-16.122	16.901	5.965
E1	161	05/19/2004	20:25:59	06/15/2005	22:25:59	5420.40	-14.299	15.068	4.357
E1	122	07/16/2005	09:26:11	06/16/2006	04:26:11	5419.19	-11.036	13.200	4.226
E2	162	05/20/2004	02:26:19	06/15/2006	20:26:19	5834.80	-14.451	28.226	5.601
E3	121	05/12/2004	06:26:37	06/15/2006	09:26:37	5966.24	-16.853	27.052	6.595
E4	137	05/14/2004	00:25:59	06/24/2005	22:25:59	6084.35	-28.339	25.609	8.447
E4	137	07/13/2005	01:31:11	06/25/2006	05:31:11	6078.01	-16.102	15.848	5.684
E4a	068	06/26/2005	11:25:59	07/12/2005	06:25:59	6080.09	0.246	13.340	2.852
E5	143	05/16/2004	14:25:59	08/20/2005	21:25:59	5902.76	-19.466	43.941	8.158
E6	156	05/20/2004	22:31:30	03/09/2006	22:31:30	6086.89	-20.296	31.973	6.826

Continued on next page

Table 11 – continued from previous page

Site	IES SN	Start Date	Start Time	End Date	End Time	Mean (dbar)	Min (mbar)	Max (mbar)	STD (mbar)
E7	170	05/25/2004	04:30:59	05/09/2005	22:30:59	6263.34	-20.782	22.159	7.053
E7	110	05/21/2004	10:25:59	09/17/2005	22:25:59	6263.84	-20.255	24.488	6.711
E7a	170	07/07/2005	15:31:11	06/11/2006	01:31:11	6262.29	-19.154	19.904	6.030
F1	114	05/30/2004	20:25:59	07/02/2005	22:25:59	5533.38	-14.525	25.956	5.752
F2	136	05/11/2004	19:25:59	04/01/2005	22:25:59	5907.72	-19.873	26.398	7.066
F2	102	06/26/2005	15:25:59	11/04/2005	22:25:59	5907.65	-15.083	19.863	4.940
F3	147	05/14/2004	06:26:35	06/25/2006	11:26:35	5930.74	-17.222	20.905	6.240
F3a	134	05/16/2004	04:30:59	03/22/2006	22:30:59	5930.79	-15.716	20.903	6.140
F4	142	05/15/2004	20:26:13	06/09/2005	09:26:13	5986.32	-21.953	29.143	7.264
F5	158	05/24/2004	10:25:59	06/10/2006	00:25:59	6157.05	-20.000	18.099	6.573
F6	174	05/24/2004	18:26:30	06/11/2006	12:26:30	6324.66	-21.532	19.568	6.700
G1	115	05/30/2004	04:26:20	03/02/2006	22:26:20	5638.42	-24.490	18.282	5.721
G2	119	05/11/2004	07:25:59	02/21/2006	22:25:59	5876.50	-22.482	20.476	5.802
G3	138	05/14/2004	15:25:59	06/26/2005	15:25:59	5870.83	-21.785	21.063	6.211
G4	109	05/15/2004	07:26:15	09/23/2005	22:26:15	6062.29	-23.069	16.815	5.552
G5	149	05/24/2004	10:25:59	09/16/2005	22:25:59	6365.59	-34.229	12.797	6.812
G6	107	05/22/2004	13:25:59	04/17/2005	22:25:59	6431.45	-24.411	16.336	6.336
H2	118	05/10/2004	08:26:36	06/13/2006	23:26:36	5766.22	-30.300	19.290	5.764
H3	112	04/30/2004	08:25:59	11/11/2005	10:25:59	5968.86	-17.929	14.124	4.637
H4	132	05/14/2004	22:25:59	08/31/2005	22:25:59	6101.35	-20.812	18.899	5.286
H5	168	05/24/2004	01:26:09	10/20/2005	22:26:09	6155.21	-22.020	19.337	5.723
H6	166	05/23/2004	01:25:59	06/12/2006	05:25:59	5853.40	-14.485	20.756	4.628
I1	163	05/29/2004	16:25:59	06/03/2006	05:25:59	5980.58	-14.191	11.564	3.790
N1	160	05/27/2004	06:26:38	06/21/2006	07:26:38	5824.13	-20.111	19.498	5.159
N1a	045	07/05/2005	09:30:59	07/22/2005	22:30:59	5822.17	-5.368	4.966	2.147
S1	101	04/27/2004	03:25:59	03/08/2005	22:25:59	6053.46	-8.006	11.742	3.803
S1	036	06/19/2005	10:30:54	06/02/2006	15:30:54	6059.10	-5.916	13.396	2.937
S2	102	04/27/2004	22:25:59	06/19/2005	09:25:59	5731.18	-10.158	11.151	3.251
S2	043	06/20/2005	00:31:08	06/02/2006	19:31:08	5735.33	-9.901	12.538	3.665

Table 11: Statistics for the hourly pressure records. Times are UT.

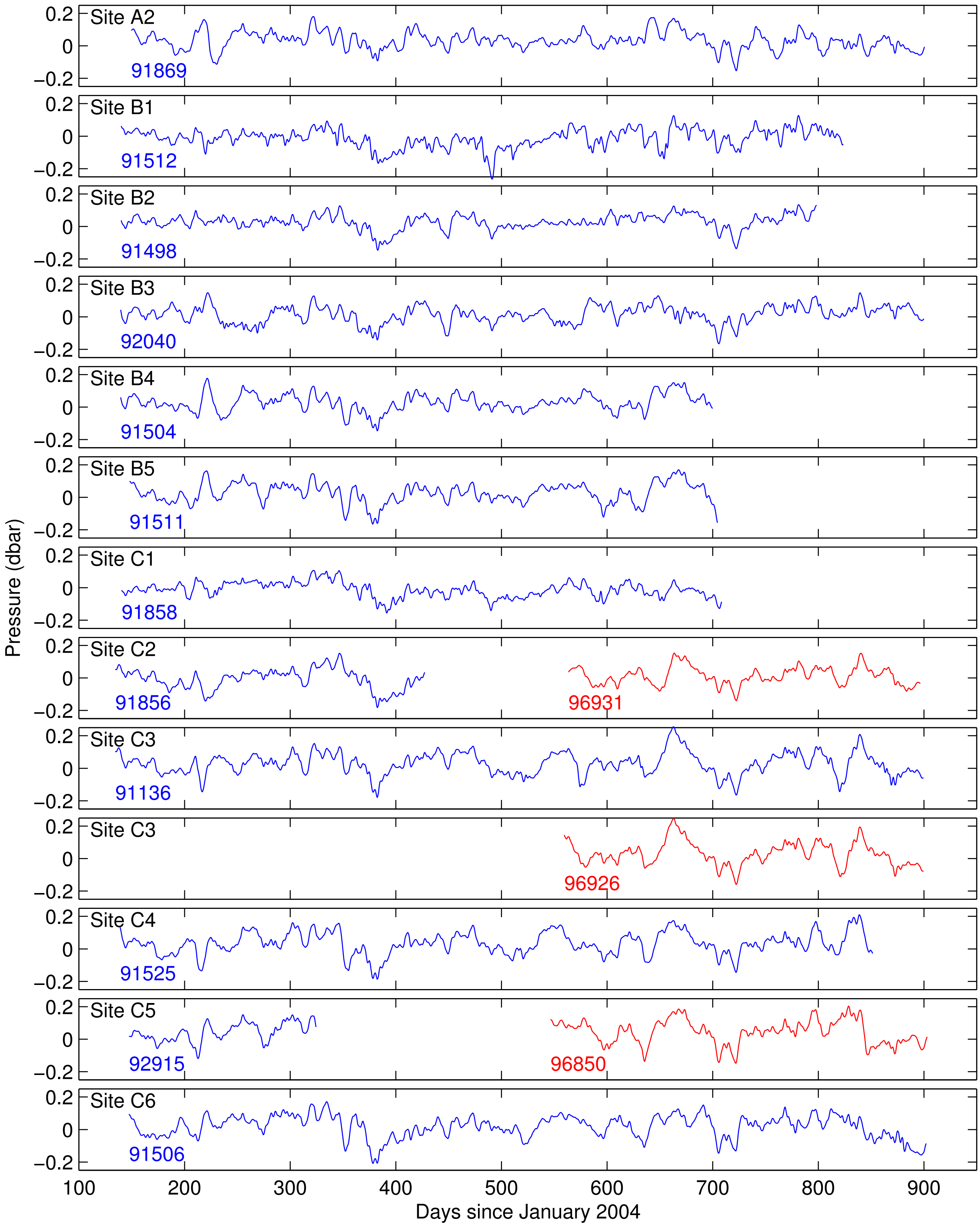


Figure 19: Time series of 72 hr lowpass filtered pressure (lines A-C). The Paroscientific pressure sensor SN is shown below the beginning of the time series.

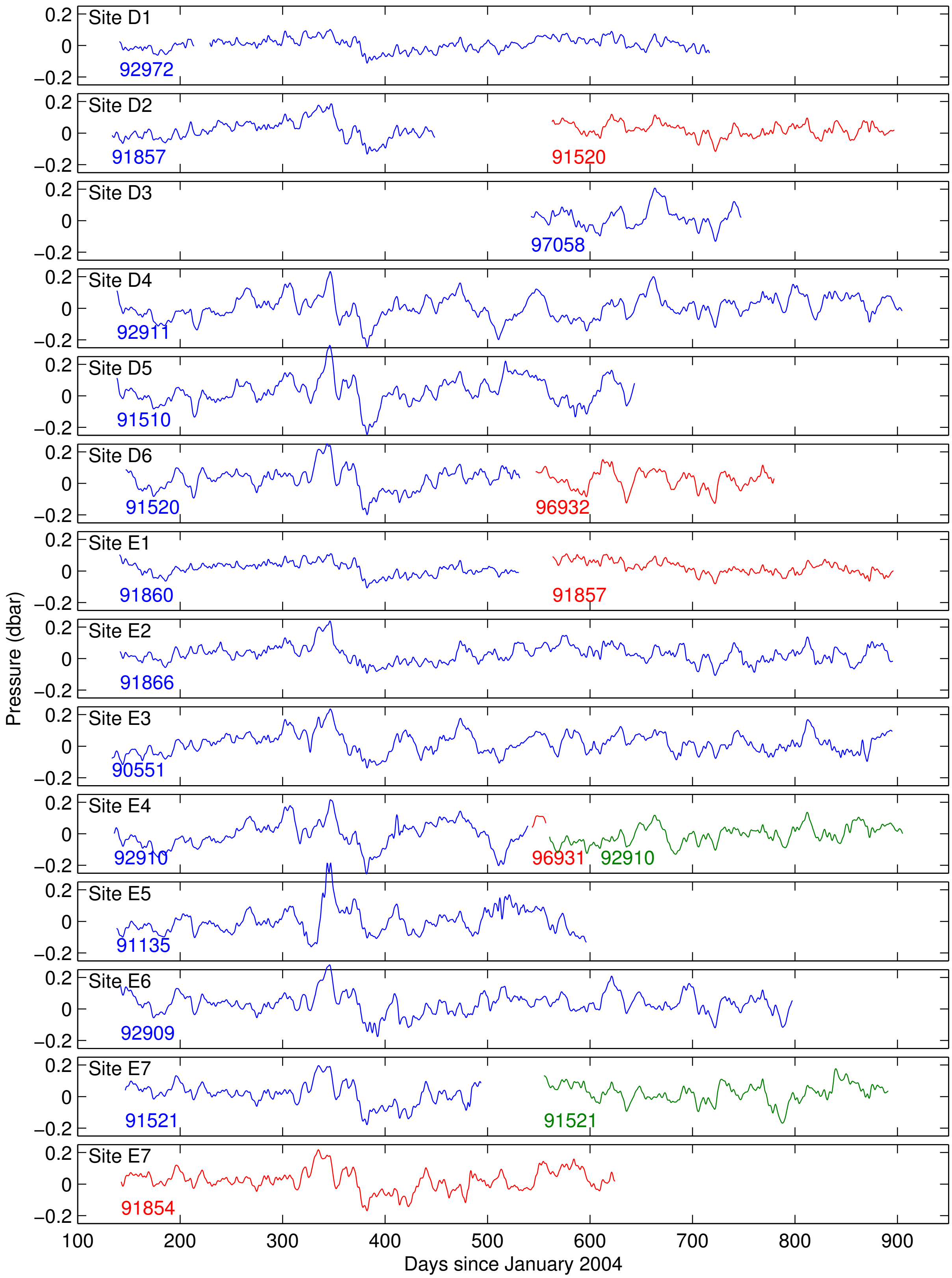


Figure 20: Time series of 72 hr lowpass filtered pressure (lines D-E). The Paroscientific pressure sensor SN is shown below the beginning of the time series.

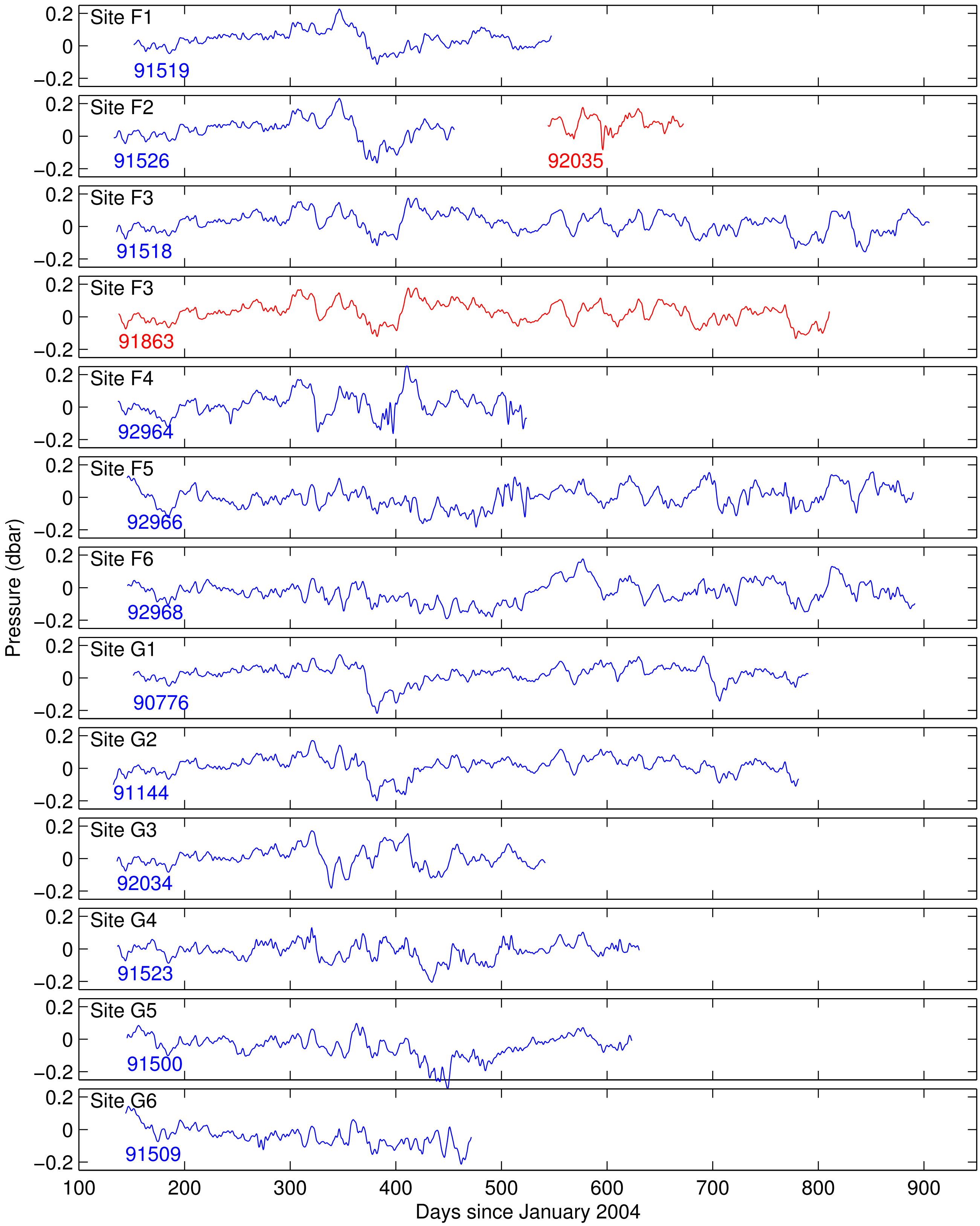


Figure 21: Time series of 72 hr lowpass filtered pressure (lines F-G). The Paroscientific pressure sensor SN is shown below the beginning of the time series.

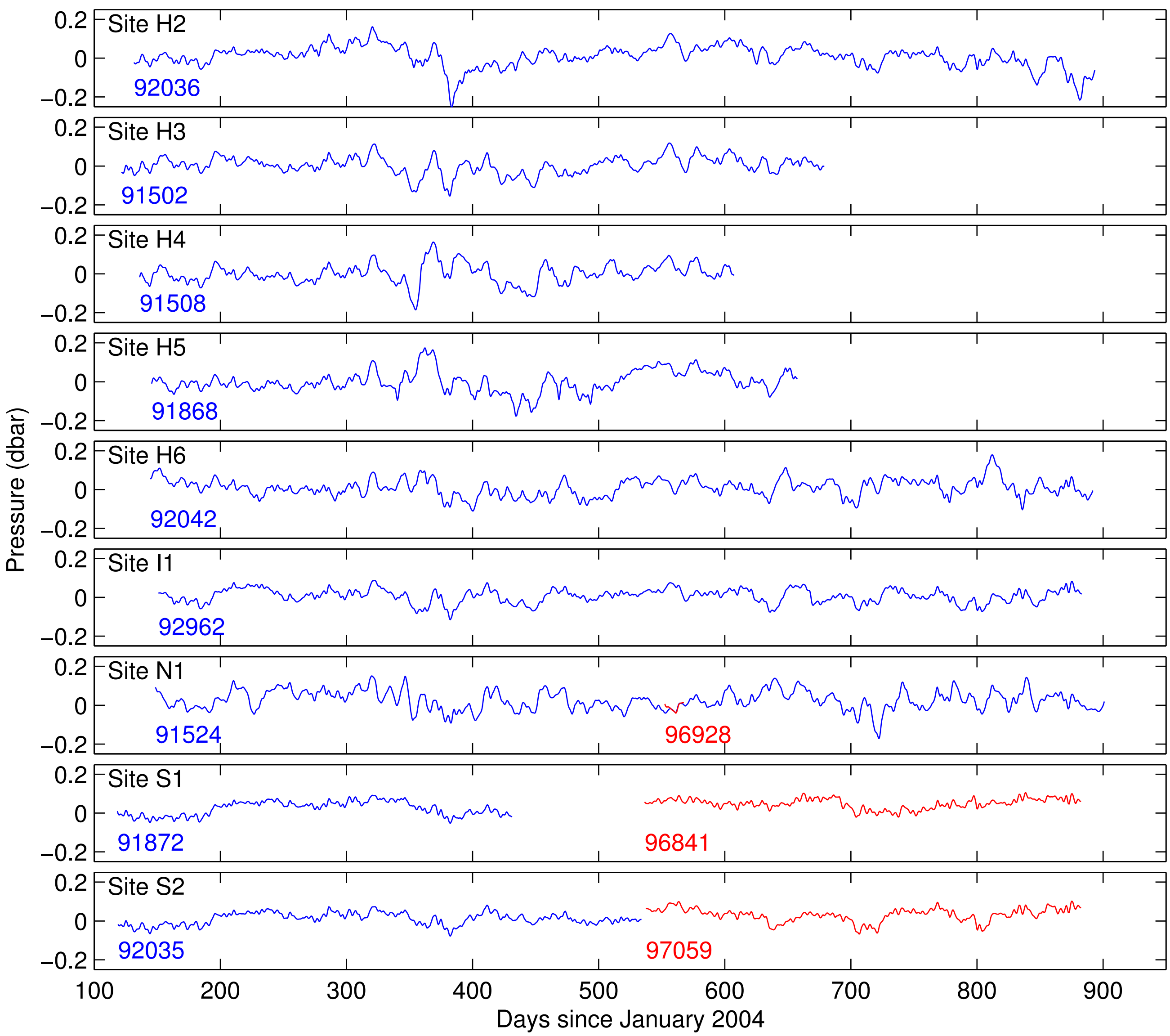


Figure 22: Time series of 72 hr lowpass filtered pressure (lines H-S). The Paroscientific pressure sensor SN is shown below the beginning of the time series.

5 Temperature Records

5.1 Paroscientific Temperature Records

Table 12 lists the coefficients of the linear fits (Equation 24) removed from the Paroscientific temperature records as described in Section 2.4.1.

Table 13 lists the mean, minimum, maximum and standard deviation of the temperature variations as well as the start and end time of the hourly temperature record for each site.

Table 12

Site	**IES SN**	**Paros SN**	**Coefficients** A_T	B_T
A2	145	91869	1.44e-06	2.375
B1	151	91512	6.38e-06	3.083
B2	152	91498	2.35e-05	2.409
B3	148	92040	4.38e-06	2.141
B4	164	91504	3.67e-05	2.812
B5	167	91511	1.93e-05	2.490
C1	153	91858	2.35e-05	2.489
C2	131	91856	2.66e-05	2.323
C3	124	91136	-3.60e-06	3.283
C3a	063	96926	-5.48e-06	1.411
C4	144	91525	1.87e-06	2.317
C5	171	92915	-2.31e-05	2.908
C5a	116	96850	1.12e-05	1.942
C6	173	91506	6.94e-06	2.477
D1	157	92972	1.11e-05	3.582
D2	122	91857	9.64e-06	2.717
D2	155	91520	-2.42e-05	2.672
D3	104	97058	-6.04e-05	1.830
D4	105	92911	-1.48e-06	2.773
D5	111	91510	3.03e-05	3.434
D6	155	91520	2.34e-05	2.675
D6	101	96932	4.00e-05	1.734
E1	161	91860	3.51e-05	2.361
E1	122	91857	-5.49e-06	2.652
E2	162	91866	-9.45e-06	2.802
E3	121	90551	-8.12e-06	2.780
E4	137	92910	1.71e-05	1.995
E4	137	92910	-1.15e-05	2.002
E4a	068	96931	1.31e-04	1.775
E5	143	91135	4.70e-05	2.375
E6	156	92909	1.58e-05	3.555
E7	170	91521	1.20e-05	2.433
E7	110	91854	3.83e-05	2.841

Continued on next page

Table 12 – from previous page

Site	IES SN	Paros SN	Coefficients A_T	B_T
E7a	170	91521	-1.10e-05	2.430
F1	114	91519	-1.25e-05	1.499
F2	136	91526	-2.40e-05	2.686
F2	102	92035	1.37e-04	2.422
F3	147	91518	5.81e-07	2.474
F3a	134	91863	2.15e-05	2.853
F4	142	92964	1.19e-05	3.202
F5	158	92966	3.55e-06	3.290
F6	174	92968	4.65e-06	2.787
G1	115	90776	2.43e-05	1.521
G2	119	91144	1.07e-06	3.184
G3	138	92034	1.95e-05	2.774
G4	109	91523	4.21e-05	2.477
G5	149	91500	3.97e-05	2.642
G6	107	91509	5.09e-05	1.013
H2	118	92036	2.41e-06	1.797
H3	112	91502	2.12e-05	2.148
H4	132	91508	4.11e-05	2.505
H5	168	91868	3.45e-05	2.326
H6	166	92042	7.79e-07	2.458
I1	163	92962	9.42e-07	3.251
N1	160	91524	4.02e-07	2.678
N1a	045	96928	2.47e-04	1.626
S1	101	91872	5.85e-05	2.557
S1	036	96841	2.27e-05	1.957
S2	102	92035	1.28e-05	2.421
S2	043	97059	-2.67e-06	1.683

Table 12: IES Serial number, Paroscientific serial number and coefficients for linear fits (Equation 24) removed from the temperature records.

Table 13

Site	IES SN	Start Date	Start Time	End Date	End Time	Min (deg)	Max (deg)	STD (deg)
A2	145	05/28/2004	03:26:32	06/20/2006	19:26:32	-0.012	0.015	4.39e-03
B1	151	05/18/2004	20:26:24	04/04/2006	22:26:24	-0.010	0.021	3.73e-03
B2	152	05/18/2004	14:26:06	03/10/2006	22:26:06	-0.017	0.022	6.36e-03
B3	148	05/18/2004	09:26:28	06/20/2006	01:26:28	-0.021	0.014	4.10e-03
B4	164	05/18/2004	00:26:25	12/02/2005	10:26:25	-0.012	0.015	4.19e-03
B5	167	05/26/2004	16:26:29	12/06/2005	22:26:29	-0.010	0.018	3.85e-03
C1	153	05/19/2004	07:26:27	12/10/2005	22:26:27	-0.012	0.018	3.78e-03

Continued on next page

Table 13 – continued from previous page

Site	IES SN	Start Date	Start Time	End Date	End Time	Min (deg)	Max (deg)	STD (deg)
C2	131	12/31/2003	23:56:44	12/31/2003	23:59:20	-0.017	0.013	4.95e-03
C3	124	05/13/2004	02:26:42	06/19/2006	20:26:42	-0.015	0.016	4.78e-03
C3a	063	07/12/2005	05:31:11	06/19/2006	18:31:11	-0.014	0.013	4.87e-03
C4	144	05/17/2004	19:26:30	05/02/2006	22:26:30	-0.014	0.019	4.41e-03
C5	171	05/26/2004	01:26:06	11/21/2004	22:26:06	-0.008	0.009	3.95e-03
C5a	116	06/29/2005	07:26:19	06/23/2006	11:26:19	-0.012	0.017	4.22e-03
C6	173	05/26/2004	10:26:43	06/22/2006	09:26:43	-0.014	0.018	4.20e-03
D1	157	05/19/2004	16:27:08	12/18/2005	22:27:08	-0.010	0.016	3.27e-03
D2	122	05/12/2004	11:26:06	03/25/2005	22:26:06	-0.016	0.011	4.46e-03
D2	155	07/15/2005	12:26:22	06/17/2006	03:26:22	-0.015	0.013	4.47e-03
D3	104	06/25/2005	02:31:20	01/18/2006	23:31:20	-0.013	0.010	4.12e-03
D4	105	05/17/2004	03:26:39	06/24/2006	19:26:39	-0.014	0.023	4.39e-03
D5	111	05/17/2004	06:26:29	10/06/2005	22:26:29	-0.020	0.021	5.99e-03
D6	155	05/25/2004	15:26:06	06/16/2005	22:26:06	-0.010	0.014	4.27e-03
D6	101	06/29/2005	20:26:06	02/19/2006	22:26:06	-0.016	0.018	4.82e-03
E1	161	05/19/2004	20:26:06	06/15/2005	22:26:06	-0.015	0.010	3.55e-03
E1	122	07/16/2005	09:26:18	06/16/2006	11:26:18	-0.015	0.011	4.21e-03
E2	162	05/20/2004	02:26:26	06/15/2006	23:26:26	-0.012	0.013	4.22e-03
E3	121	05/12/2004	06:26:44	06/15/2006	14:26:44	-0.015	0.018	5.37e-03
E4	137	05/14/2004	00:26:06	06/24/2005	22:26:06	-0.018	0.019	4.65e-03
E4	137	07/13/2005	01:31:18	06/25/2006	05:31:18	-0.010	0.013	3.40e-03
E4a	068	06/26/2005	11:26:06	07/12/2005	06:26:06	-0.007	0.006	2.43e-03
E5	143	05/16/2004	14:26:06	08/20/2005	21:26:06	-0.017	0.023	6.12e-03
E6	156	05/20/2004	22:31:37	03/09/2006	22:31:37	-0.015	0.017	4.81e-03
E7	170	05/25/2004	04:31:06	05/09/2005	22:31:06	-0.013	0.018	4.62e-03
E7	110	05/21/2004	10:26:06	09/17/2005	22:26:06	-0.013	0.018	4.80e-03
E7a	170	07/07/2005	15:31:18	06/11/2006	01:31:18	-0.013	0.019	4.69e-03
F1	114	05/30/2004	20:26:06	07/02/2005	22:26:06	-0.016	0.010	4.73e-03
F2	136	05/11/2004	19:26:06	04/01/2005	22:26:06	-0.014	0.019	4.95e-03
F2	102	06/26/2005	15:26:06	11/04/2005	22:26:06	-0.013	0.018	4.63e-03
F3	147	05/14/2004	06:26:42	06/25/2006	11:26:42	-0.022	0.017	5.33e-03
F3a	134	05/16/2004	04:31:06	03/22/2006	22:31:06	-0.018	0.024	5.49e-03
F4	142	05/15/2004	20:26:20	06/09/2005	09:26:20	-0.018	0.018	5.95e-03
F5	158	05/24/2004	10:26:06	06/10/2006	00:26:06	-0.015	0.021	3.56e-03
F6	174	05/24/2004	18:26:37	06/11/2006	12:26:37	-0.015	0.018	3.99e-03
G1	115	05/30/2004	04:26:27	03/02/2006	22:26:27	-0.018	0.016	5.57e-03
G2	119	05/11/2004	07:26:06	02/21/2006	22:26:06	-0.021	0.044	4.36e-03
G3	138	05/14/2004	15:26:06	06/26/2005	22:26:06	-0.014	0.021	4.41e-03
G4	109	05/15/2004	07:26:22	09/23/2005	22:26:22	-0.015	0.031	5.29e-03
G5	149	05/24/2004	10:26:06	09/16/2005	22:26:06	-0.015	0.020	4.98e-03
G6	107	05/22/2004	13:26:06	04/17/2005	22:26:06	-0.015	0.026	4.71e-03
H2	118	05/10/2004	08:26:43	06/13/2006	23:26:43	-0.015	0.017	3.60e-03
H3	112	04/30/2004	08:26:06	11/11/2005	21:26:06	-0.013	0.018	5.21e-03
H4	132	05/14/2004	22:26:06	08/31/2005	22:26:06	-0.014	0.016	4.77e-03

Continued on next page

Table 13 – continued from previous page

Site	IES SN	Start Date	Start Time	End Date	End Time	Min (deg)	Max (deg)	STD (deg)
H5	168	05/24/2004	01:26:16	10/20/2005	22:26:16	-0.013	0.022	4.67e-03
H6	166	05/23/2004	01:26:06	06/12/2006	10:26:06	-0.014	0.023	5.67e-03
I1	163	05/29/2004	16:26:06	06/03/2006	05:26:06	-0.011	0.013	4.92e-03
N1	160	05/27/2004	06:26:45	06/21/2006	07:26:45	-0.011	0.016	3.64e-03
N1a	045	07/05/2005	09:31:06	07/22/2005	22:31:06	-0.002	0.006	1.57e-03
S1	101	04/27/2004	03:26:06	03/08/2005	22:26:06	-0.016	0.012	4.51e-03
S1	036	06/19/2005	10:31:01	06/02/2006	15:31:01	-0.010	0.011	3.48e-03
S2	102	04/27/2004	22:26:06	06/19/2005	04:26:06	-0.006	0.006	2.09e-03
S2	043	06/20/2005	00:31:15	06/03/2006	00:31:15	-0.009	0.009	4.32e-03

Table 13: Statistics for the hourly Paroscientific temperature records. Time in UT.

5.2 DCS Temperature Records

Table 14 lists the coefficients of the linear fits (Equation 24) removed from the DCS temperature records as described in Section 2.4.2.

Table 15 lists the minimum, maximum and standard deviation of the temperature variations as well as the start and end time of the hourly DCS temperature record for each site.

Table 14

Site	IES SN	DCS SN	Coefficients A_T	Coefficients B_T
A2	145	318	-5.40e-06	1.343
B1	151	311	-3.22e-06	1.364
B2	152	313	-1.12e-05	1.350
B3	148	337	-1.39e-05	1.343
B5	167	317	-1.06e-05	1.344
C1	153	316	-8.17e-06	1.416
C2	131	501	1.61e-05	1.370
C3	124	354	7.32e-05	1.383
C4	144	324	-9.96e-06	1.318
C5	171	504	-5.05e-05	1.442
C5a	116	305	-1.09e-05	1.412
C6	173	174	2.29e-05	1.282
D1	157	310	-5.34e-06	1.438
D2	122	357	9.12e-06	1.432
D3	104	346	-8.81e-05	1.468
D5	111	344	2.23e-05	1.393
D6	155	201	-3.51e-05	1.363

Continued on next page

Table 14 – from previous page

Site	IES SN	DCS SN	Coefficients A_T	B_T
D6	101	165	-9.27e-05	1.305
E1	161	338	-2.26e-05	1.323
E2	162	339	-1.82e-05	1.354
E3	121	308	-1.02e-06	1.355
E4	137	355	-1.20e-05	1.466
E5	143	322	8.30e-06	1.391
E6	156	306	4.27e-07	1.431
E7	170	320	-6.02e-06	1.379
E7	110	352	4.13e-06	1.459
F1	114	359	-3.62e-05	1.432
F2	136	350	-4.02e-05	1.400
F2	102	309	2.20e-05	1.457
F4	142	171	-7.08e-05	1.364
F5	158	312	-8.43e-06	1.406
F6	174	348	-6.15e-06	1.413
G1	115	336	6.81e-06	1.318
G2	119	351	-8.28e-06	1.379
G3	138	358	-3.49e-05	1.433
G4	109	503	-2.55e-05	1.317
G5	149	342	3.37e-06	1.431
G6	107	347	4.78e-06	1.382
H2	118	343	1.94e-05	1.358
H3	112	356	-3.04e-05	1.437
H4	132	503	-1.47e-05	1.444
H5	168	340	-6.32e-06	1.429
H6	166	323	-1.22e-05	1.408
I1	163	502	-1.39e-05	1.444
N1	160	307	-4.89e-06	1.395
N1a	045	166	-1.27e-04	1.236
S1	101	341	-1.52e-05	1.408
S2	102	309	2.84e-06	1.436
S2	043	164	-1.84e-05	1.293

Table 14: IES Serial number, DCS serial number and coefficients for linear fits (Equation 24) removed from the DCS temperature records.

Table 15

Site	IES SN	Start Date	Start Time	End Date	End Time	Min (deg)	Max (deg)	STD (deg)
A2	145	05/27/2004	04:22:39	06/20/2006	20:22:39	-0.014	0.021	4.72e-03
B1	151	05/18/2004	06:22:31	04/05/2006	01:22:31	-0.012	0.020	3.99e-03
B2	152	05/18/2004	01:22:12	12/06/2005	17:22:12	-0.015	0.032	5.64e-03
B3	148	05/17/2004	17:22:34	09/14/2005	18:22:34	-0.017	0.016	4.48e-03
B5	167	05/26/2004	02:22:35	12/07/2005	19:22:35	-0.014	0.016	4.41e-03
C1	153	05/18/2004	14:22:34	11/08/2005	07:22:34	-0.012	0.013	3.90e-03
C2	131	05/12/2004	07:22:12	03/05/2005	06:22:12	-0.021	0.016	4.56e-03
C3	124	05/12/2004	13:22:49	05/21/2004	02:22:49	-0.004	0.007	3.79e-03
C4	144	05/16/2004	23:22:36	05/03/2006	12:22:36	-0.022	0.015	5.12e-03
C5	171	05/25/2004	06:22:12	12/26/2004	04:22:12	-0.015	0.011	4.08e-03
C5a	116	06/27/2004	20:22:29	06/22/2005	09:22:29	-0.019	0.019	5.41e-03
C6	173	05/25/2004	15:22:49	04/24/2006	03:22:49	-0.024	0.027	7.12e-03
D1	157	05/18/2004	23:23:14	12/19/2005	16:23:14	-0.013	0.010	3.56e-03
D2	122	05/12/2004	01:22:11	03/26/2005	22:22:12	-0.015	0.010	4.97e-03
D3	104	06/23/2004	19:27:29	01/18/2005	14:27:29	-0.017	0.017	5.84e-03
D5	111	08/08/2004	00:22:35	10/07/2005	15:22:35	-0.017	0.019	5.24e-03
D6	155	05/25/2004	00:22:12	06/28/2005	23:22:12	-0.083	0.015	4.36e-03
D6	101	10/28/2004	00:22:15	02/19/2005	19:22:15	-0.022	0.015	6.31e-03
E1	161	05/19/2004	05:22:12	06/17/2005	17:22:12	-0.017	0.015	3.55e-03
E2	162	05/19/2004	11:22:32	06/04/2006	02:22:32	-0.018	0.016	4.56e-03
E3	121	05/11/2004	11:22:50	08/21/2005	21:22:50	-0.018	0.021	5.24e-03
E4	137	05/13/2004	07:22:12	05/05/2005	18:22:16	-0.020	0.025	5.01e-03
E5	143	05/15/2004	23:22:12	08/21/2005	02:22:12	-0.022	0.032	6.20e-03
E6	156	05/20/2004	07:27:43	07/09/2005	09:27:43	-0.016	0.031	4.92e-03
E7	170	05/24/2004	13:27:12	05/10/2005	13:27:12	-0.018	0.022	4.87e-03
E7	110	05/20/2004	13:22:12	09/17/2005	06:22:12	-0.018	0.025	5.20e-03
F1	114	05/30/2004	00:22:12	07/04/2005	12:22:12	-0.017	0.012	3.41e-03
F2	136	05/11/2004	04:22:12	04/02/2005	01:22:12	-0.019	0.023	5.85e-03
F2	102	06/25/2004	00:22:15	11/04/2004	17:22:15	-0.019	0.013	4.10e-03
F4	142	05/15/2004	02:22:27	07/05/2005	17:22:27	-0.022	0.024	6.08e-03
F5	158	05/23/2004	16:22:12	06/10/2006	01:22:12	-0.018	0.025	5.08e-03
F6	174	05/24/2004	04:22:43	11/13/2005	01:22:43	-0.014	0.026	4.81e-03
G1	115	05/29/2004	14:22:33	11/17/2005	01:22:33	-0.020	0.018	4.85e-03
G2	119	05/10/2004	15:22:12	02/23/2006	21:22:12	-0.024	0.021	4.89e-03
G3	138	05/14/2004	00:22:12	06/27/2005	09:22:12	-0.014	0.021	4.80e-03
G4	109	05/14/2004	14:22:29	09/24/2005	01:22:29	-0.017	0.017	4.79e-03
G5	149	07/19/2004	00:22:12	09/17/2005	06:22:12	-0.016	0.024	4.85e-03
G6	107	05/21/2004	23:22:12	04/18/2005	04:22:12	-0.010	0.023	4.72e-03
H2	118	02/04/2005	00:22:49	06/13/2006	23:22:50	-0.016	0.021	5.17e-03
H3	112	04/29/2004	18:27:12	09/29/2005	04:27:12	-0.017	0.017	4.64e-03
H4	132	05/14/2004	08:22:12	09/01/2005	21:22:12	-0.017	0.018	5.38e-03
H5	168	05/23/2004	00:22:22	10/21/2005	09:22:22	-0.018	0.015	4.81e-03
H6	166	05/22/2004	11:22:12	04/12/2006	07:22:12	-0.022	0.027	5.93e-03

Continued on next page

Table 15 – continued from previous page

Site	IES SN	Start Date	Start Time	End Date	End Time	Min (deg)	Max (deg)	STD (deg)
I1	163	05/29/2004	01:22:12	06/03/2006	07:22:12	-0.019	0.015	5.35e-03
N1	160	05/26/2004	15:22:51	06/15/2006	05:22:51	-0.013	0.020	3.72e-03
N1a	045	07/03/2004	16:27:15	07/21/2004	23:27:15	-0.012	0.010	3.07e-03
S1	101	04/26/2004	12:27:12	03/09/2005	15:27:12	-0.010	0.009	2.47e-03
S2	102	04/27/2004	05:27:12	05/08/2005	04:27:12	-0.007	0.006	2.82e-03
S2	043	06/18/2004	09:27:22	06/02/2005	00:27:22	-0.014	0.014	4.67e-03

Table 15: Statistics for the hourly DCS temperature records. Time in UT.

5.3 Temperature Variation Comparsions

Lowpass filtered temperature variations for the Paroscientific (color) and DCS (black) sensors are plotted in Figures 23-26. Paroscientific and DCS serial numbers are shown below the beginning of the time series.

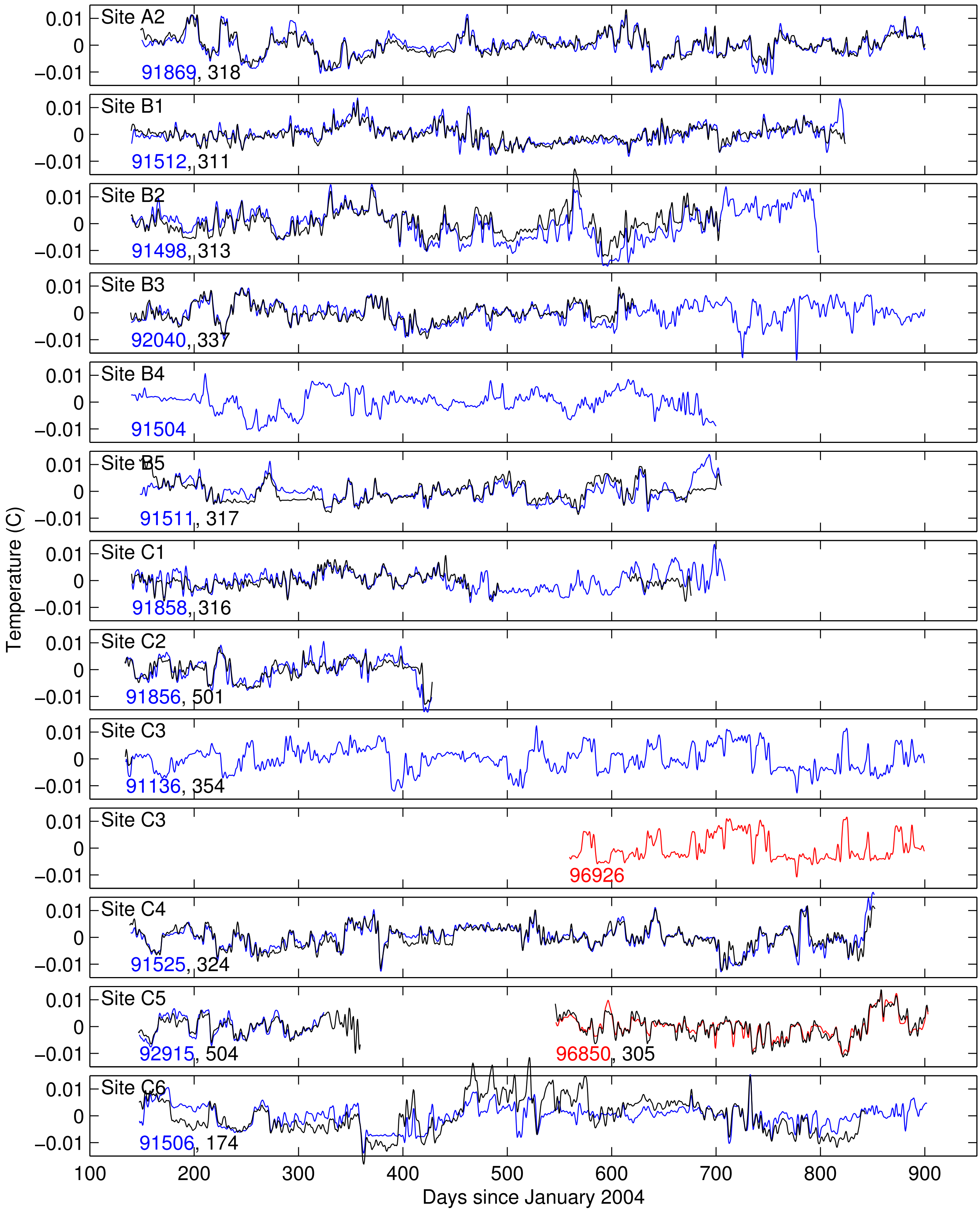


Figure 23: Time series of 72 hr lowpass filtered temperature variations for the Paroscientific (color) and DCS (black) sensors (lines A-C). Paroscientific and DCS SNs are shown below the beginning of the time series.

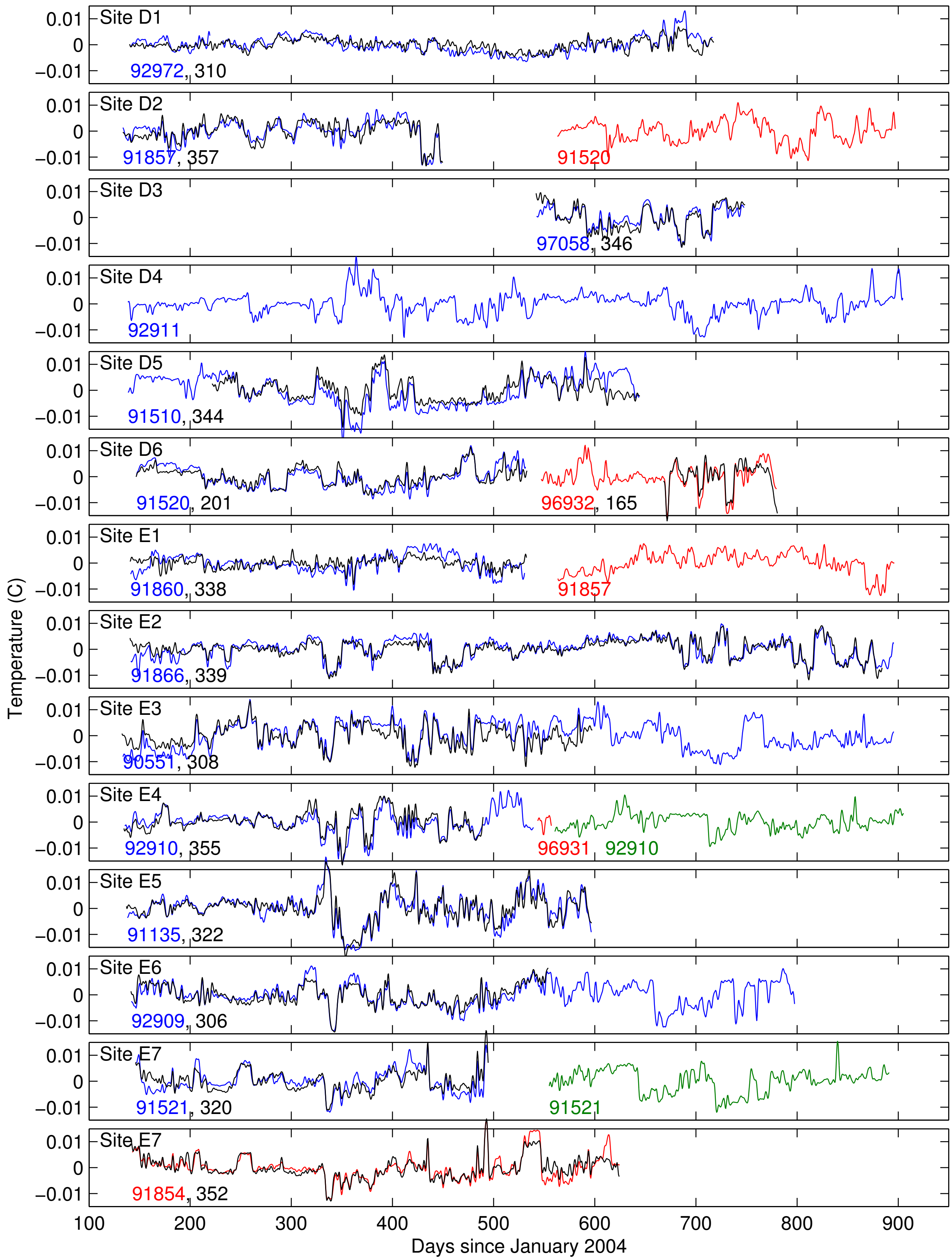


Figure 24: Time series of 72 hr lowpass filtered temperature variations for the Paroscientific (color) and DCS (black) sensors (lines D-E). Paroscientific and DCS SNs are shown below the beginning of the time series.

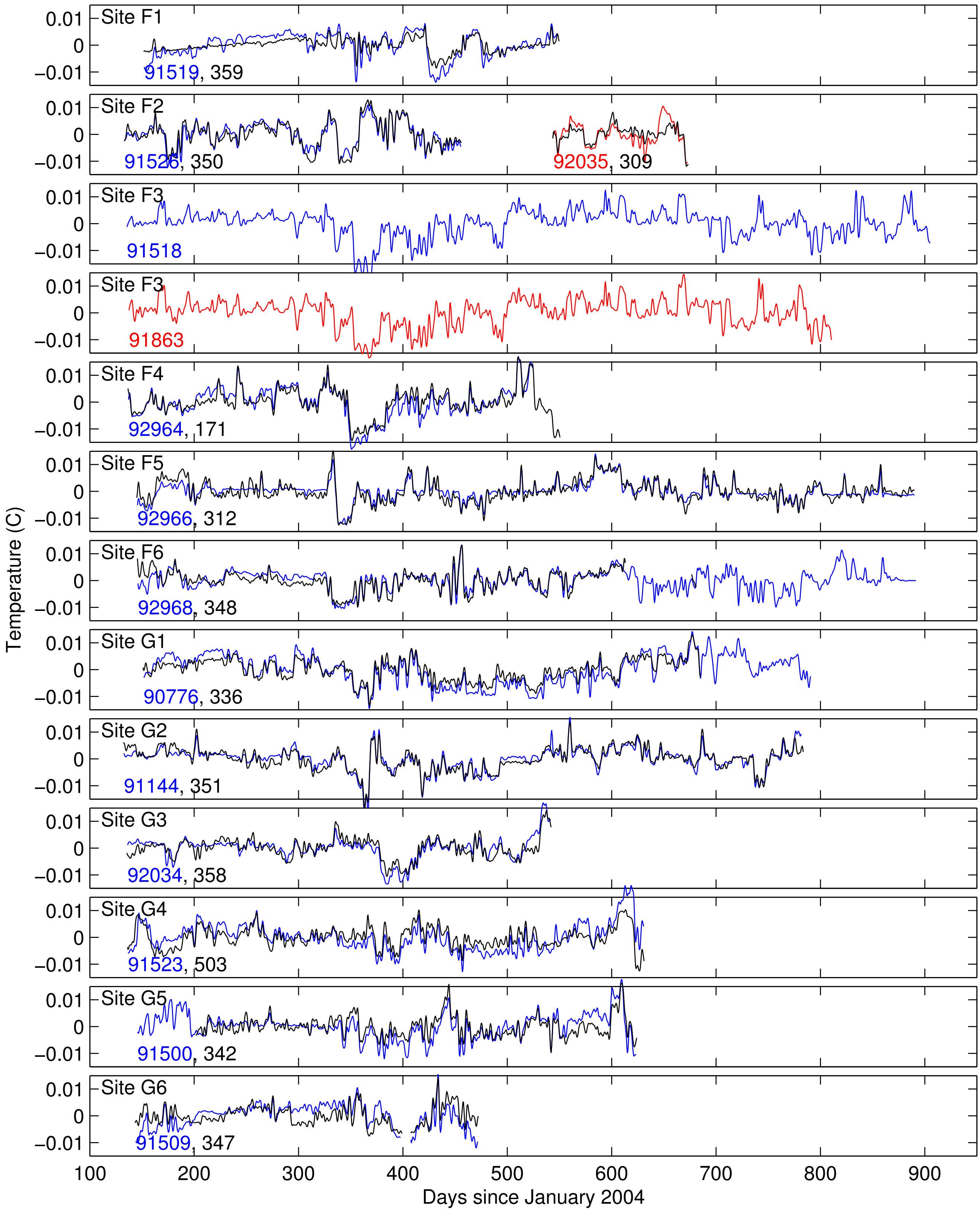


Figure 25: Time series of 72 hr lowpass filtered temperature variations for the Paroscientific (color) and DCS (black) sensors (lines F-G). Paroscientific and DCS SNs are shown below the beginning of the time series.

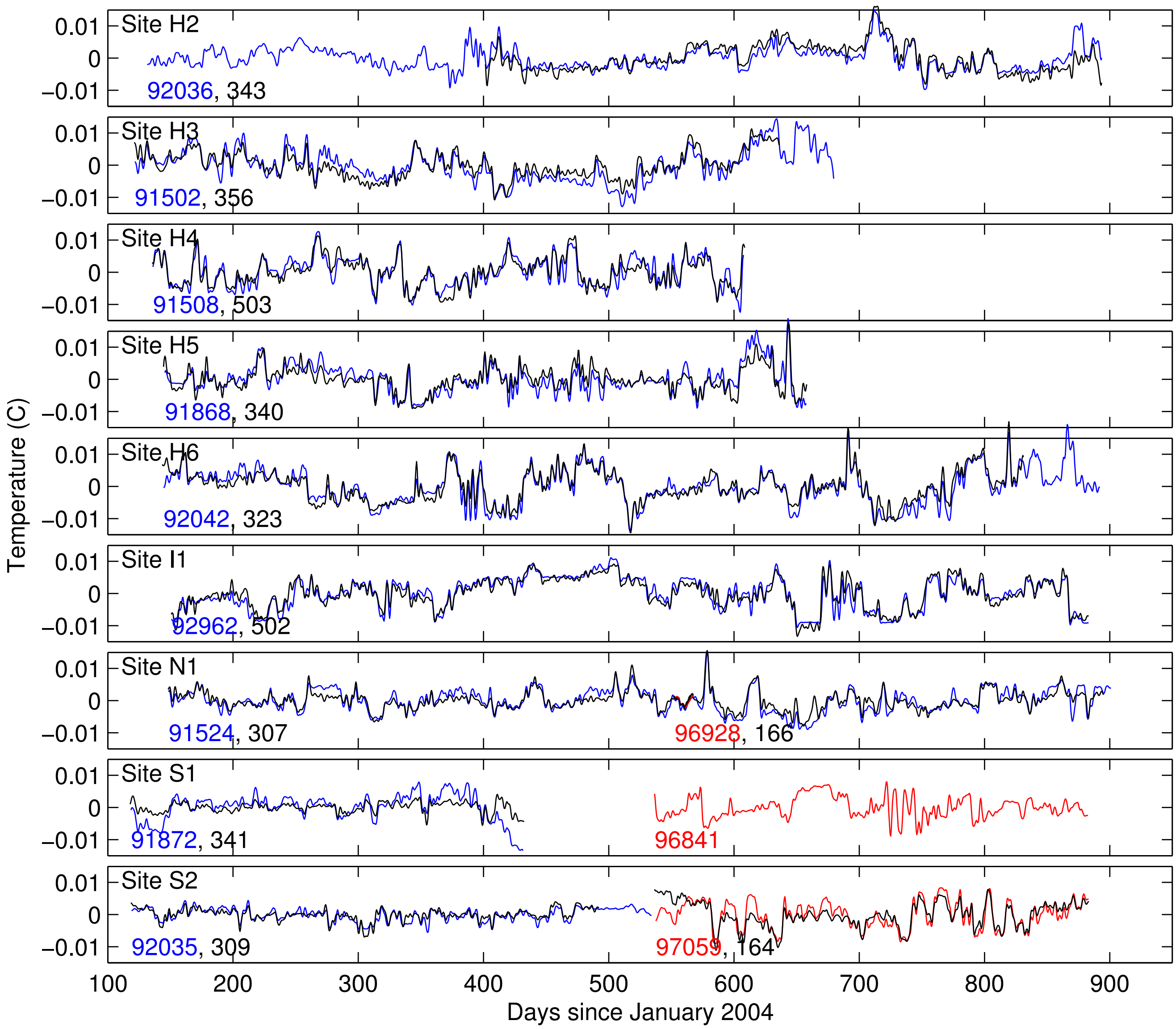


Figure 26: Time series of 72 hr lowpass filtered temperature variations for the Paroscientific (color) and DCS (black) sensors (lines H-S). Paroscientific and DCS SNs are shown below the beginning of the time series.

6 Current Records

Table 16 lists the mean, minimum, maximum and standard deviation of hourly u and v velocities as well as the start and end time of the DCS u, v record for each site. Lowpass filtered DCS u (color) and v (black) records are shown in Figures 27-30. DCS serial number is shown below the beginning of the time series for each instrument.

Table 16

Site	IES SN	Start Date	Start Time	End Date	End Time	Mean u $cm\,s^{-1}$	Mean v $cm\,s^{-1}$	Min u $cm\,s^{-1}$	Min v $cm\,s^{-1}$	Max u $cm\,s^{-1}$	Max v $cm\,s^{-1}$	STD u $cm\,s^{-1}$	STD v $cm\,s^{-1}$
A2	145	05/27/04	7:22:40	06/20/06	20:22:39	1.33	-0.10	-24.52	-18.31	26.15	20.20	7.50	6.53
B1	151	05/18/04	6:22:31	04/05/06	1:22:31	-6.53	6.97	-58.00	-24.35	20.88	31.28	10.14	6.62
B2	152	05/17/04	22:22:12	12/06/05	17:22:12	0.34	1.08	-24.67	-39.59	36.76	35.91	6.83	8.88
B3	148	05/17/04	14:22:34	09/14/05	18:22:34	5.04	-2.34	-28.08	-28.41	31.15	20.57	8.80	6.16
B5	167	05/25/04	23:22:35	12/07/05	19:22:35	-2.51	-3.22	-24.92	-22.56	15.88	16.89	6.33	6.13
C1	153	05/18/04	12:22:34	11/08/05	8:22:34	8.08	-6.67	-11.42	-45.44	56.44	26.76	8.21	8.77
C2	131	05/12/04	8:22:12	03/05/05	6:22:12	1.14	1.18	-15.46	-21.06	24.70	19.20	5.83	5.88
C3	124	05/12/04	11:22:49	05/21/04	2:22:49	-3.77	-1.79	-12.87	-11.66	5.16	7.07	3.72	3.91
C4	144	05/16/04	22:22:36	05/03/06	12:22:36	-0.89	0.56	-24.59	-21.27	29.67	27.95	7.58	6.56
C5	171	05/25/04	5:22:12	12/26/04	4:22:12	-2.82	-0.06	-16.33	-16.06	29.77	20.04	6.50	6.48
C5a	116	06/28/05	18:22:29	06/23/06	9:22:29	0.63	0.09	-18.63	-24.10	30.06	22.50	7.78	7.61
C6	173	05/25/04	15:22:49	04/24/06	6:23:44	0.63	-2.97	-17.62	-23.86	25.96	18.21	6.01	5.87
D1	157	05/18/04	22:23:14	12/19/05	16:23:14	4.23	0.02	-9.73	-34.82	17.24	20.45	3.99	7.56
D2	122	05/12/04	0:22:12	03/26/05	20:22:12	1.32	-1.14	-27.25	-19.11	35.17	15.76	6.45	5.72
D3	104	06/24/05	15:27:29	01/19/06	14:27:29	-2.95	-4.57	-24.78	-36.03	15.50	19.86	7.25	7.75
D5	111	05/16/04	11:22:35	10/07/05	15:22:35	-0.59	5.30	-23.15	-11.46	30.83	33.97	7.02	6.70
D6	155	05/25/04	0:22:12	06/18/05	6:22:12	-3.59	-3.12	-20.19	-41.72	14.23	15.88	5.07	7.43
D6	101	06/29/05	3:22:15	02/20/06	19:22:15	-4.98	-3.75	-18.88	-27.74	17.59	20.93	5.99	7.77
E1	161	05/19/04	5:22:12	06/17/05	17:22:12	4.10	4.82	-9.88	-10.43	25.44	24.89	4.53	4.97
E2	162	05/19/04	10:22:32	06/04/06	2:22:32	2.71	2.67	-18.41	-18.17	27.02	28.14	5.45	6.09
E3	121	05/11/04	10:22:50	08/21/05	20:22:56	1.87	-3.37	-24.90	-30.62	21.09	50.94	6.27	10.71
E4	137	05/13/04	5:22:12	05/05/05	19:22:20	4.11	-2.76	-23.64	-27.66	33.15	22.11	8.05	7.48
E5	143	05/15/04	23:22:12	08/21/05	0:22:12	-4.61	8.64	-53.09	-20.87	16.62	61.97	8.82	13.33
E6	156	05/20/04	4:27:43	07/09/05	9:27:43	-2.48	-2.61	-40.81	-25.43	37.14	25.42	9.58	7.81
E7	170	05/24/04	10:27:12	05/10/05	13:27:12	-2.97	3.17	-31.56	-29.34	24.71	27.64	7.22	6.62
E7	110	05/20/04	12:22:12	09/17/05	6:22:12	-0.46	1.23	-27.27	-24.85	27.08	25.80	7.49	6.98
F1	114	05/29/04	22:22:12	07/04/05	12:22:12	1.63	0.35	-13.43	-19.08	20.35	28.37	5.22	5.49
F2	136	05/11/04	4:22:12	04/02/05	1:22:12	-2.75	-2.76	-29.28	-45.38	21.21	32.20	6.79	8.80
F2	102	06/25/05	22:22:15	11/05/05	17:22:15	-3.86	-9.89	-26.33	-47.55	38.88	28.74	7.56	9.04
F4	142	05/15/04	1:22:27	07/05/05	17:22:27	3.36	-6.77	-33.81	-48.12	44.77	37.92	7.83	9.87

Continued on next page

Table 16 – continued from previous page

Site	IES SN	Start Date	Start Time	End Date	End Time	Mean u $cm\,s^{-1}$	Mean v $cm\,s^{-1}$	Min u $cm\,s^{-1}$	Min v $cm\,s^{-1}$	Max u $cm\,s^{-1}$	Max v $cm\,s^{-1}$	STD u $cm\,s^{-1}$	STD v $cm\,s^{-1}$
F5	158	05/24/04	2:22:12	06/10/06	1:22:12	-5.00	-4.25	-47.76	-49.12	18.34	30.19	7.33	10.28
F6	174	05/24/04	2:22:43	11/12/05	14:22:43	-11.17	-0.82	-46.62	-29.40	16.64	20.23	9.94	5.64
G1	115	05/29/04	14:22:33	11/17/05	1:22:33	-1.05	2.13	-30.60	-12.96	22.27	19.51	5.67	4.52
G2	119	05/10/04	14:22:12	02/23/06	21:22:12	-2.39	-1.24	-29.89	-26.42	15.73	36.40	6.02	7.03
G3	138	05/14/04	1:22:12	06/27/05	9:22:12	-4.88	-0.97	-37.45	-29.21	14.98	35.88	8.50	8.37
G4	109	05/14/04	12:22:29	09/24/05	1:22:29	-2.93	-4.27	-49.33	-47.88	25.32	21.64	7.18	7.83
G5	149	05/23/04	6:22:12	09/17/05	6:22:12	5.20	1.03	-18.59	-23.46	26.31	46.91	7.00	7.61
G6	107	05/21/04	22:22:12	04/18/05	4:22:12	5.23	0.69	-16.49	-25.53	31.24	37.89	7.16	6.59
H2	118	05/09/04	14:22:50	06/13/06	23:22:50	-0.51	-1.37	-36.03	-32.99	28.39	25.75	6.24	5.69
H3	112	04/29/04	18:27:12	09/29/05	4:27:12	-1.42	-2.40	-16.45	-22.13	19.79	29.26	4.78	6.64
H4	132	05/14/04	8:22:12	09/01/05	21:22:12	1.61	-0.19	-27.75	-25.69	25.94	33.35	7.98	7.00
H5	168	05/23/04	0:22:22	10/21/05	1:22:22	3.64	-0.95	-18.26	-28.44	39.04	17.62	8.16	6.44
H6	166	05/22/04	9:22:12	04/12/06	7:22:12	8.20	-2.75	-29.25	-22.88	38.44	26.23	11.20	5.62
I1	163	05/29/04	1:22:12	06/03/06	7:22:12	-1.39	2.66	-14.61	-20.83	11.35	21.35	3.58	5.19
N1	160	05/26/04	15:22:51	06/15/06	5:22:51	-1.05	-0.47	-18.36	-21.57	19.88	29.40	5.30	6.53
N1a	45	07/04/05	21:27:15	07/22/05	23:27:15	5.99	1.64	-3.84	-8.82	13.31	9.85	3.40	4.00
S1	101	04/26/04	10:27:12	03/09/05	15:27:12	0.15	1.34	-12.90	-15.10	11.23	26.76	3.28	5.77
S1	36	06/18/05	21:27:07	06/02/06	15:27:07	-0.67	2.67	-12.63	-18.49	12.89	25.52	3.63	7.58
S2	102	04/27/04	4:27:12	05/08/05	4:27:12	3.82	-5.41	-5.59	-18.80	15.95	7.15	3.14	3.70
S2	43	06/19/05	8:27:22	06/02/06	20:27:22	4.77	-5.87	-7.45	-23.36	17.68	7.70	3.82	4.70

Table 16: Statistics for the hourly DCS u, v records. Time in UT.

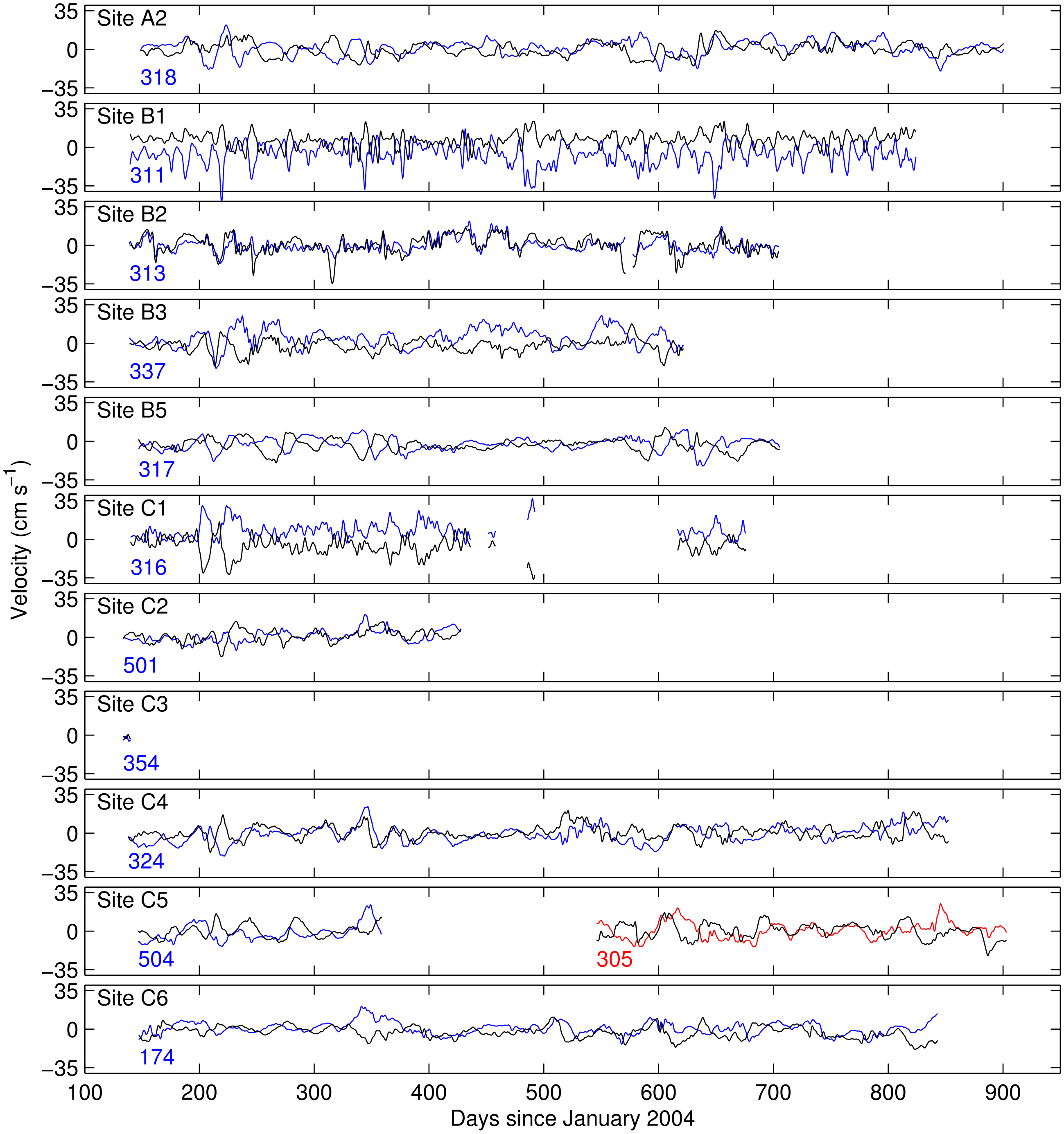


Figure 27: Time series of 72 hr lowpass filtered currents (lines A-C). The DCS SN is shown below the beginning of the time series. u is shown in color and v in black.

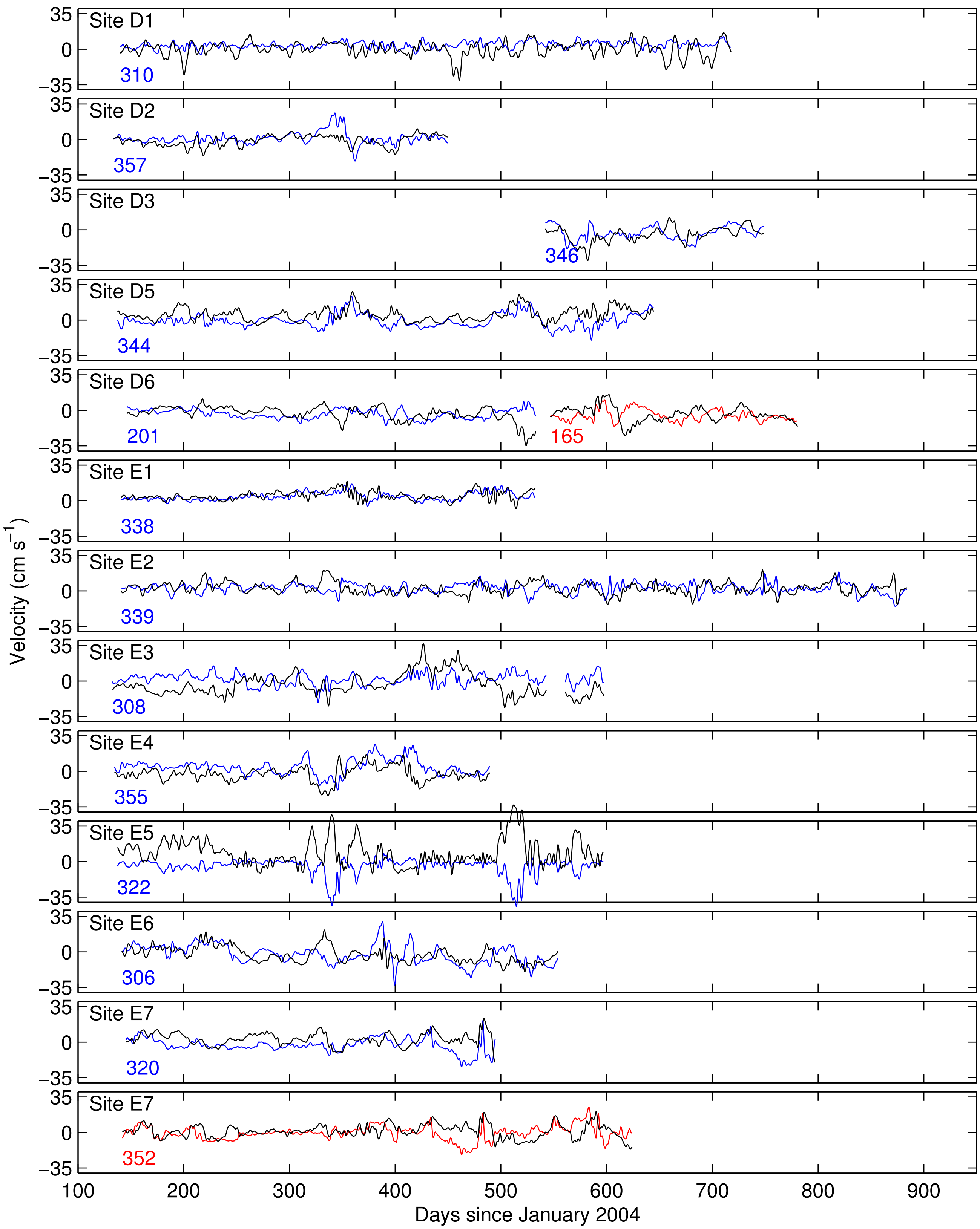


Figure 28: Time series of 72 hr lowpass filtered currents (lines D-E). The DCS SN is shown below the beginning of the time series. u is shown in color and v in black.

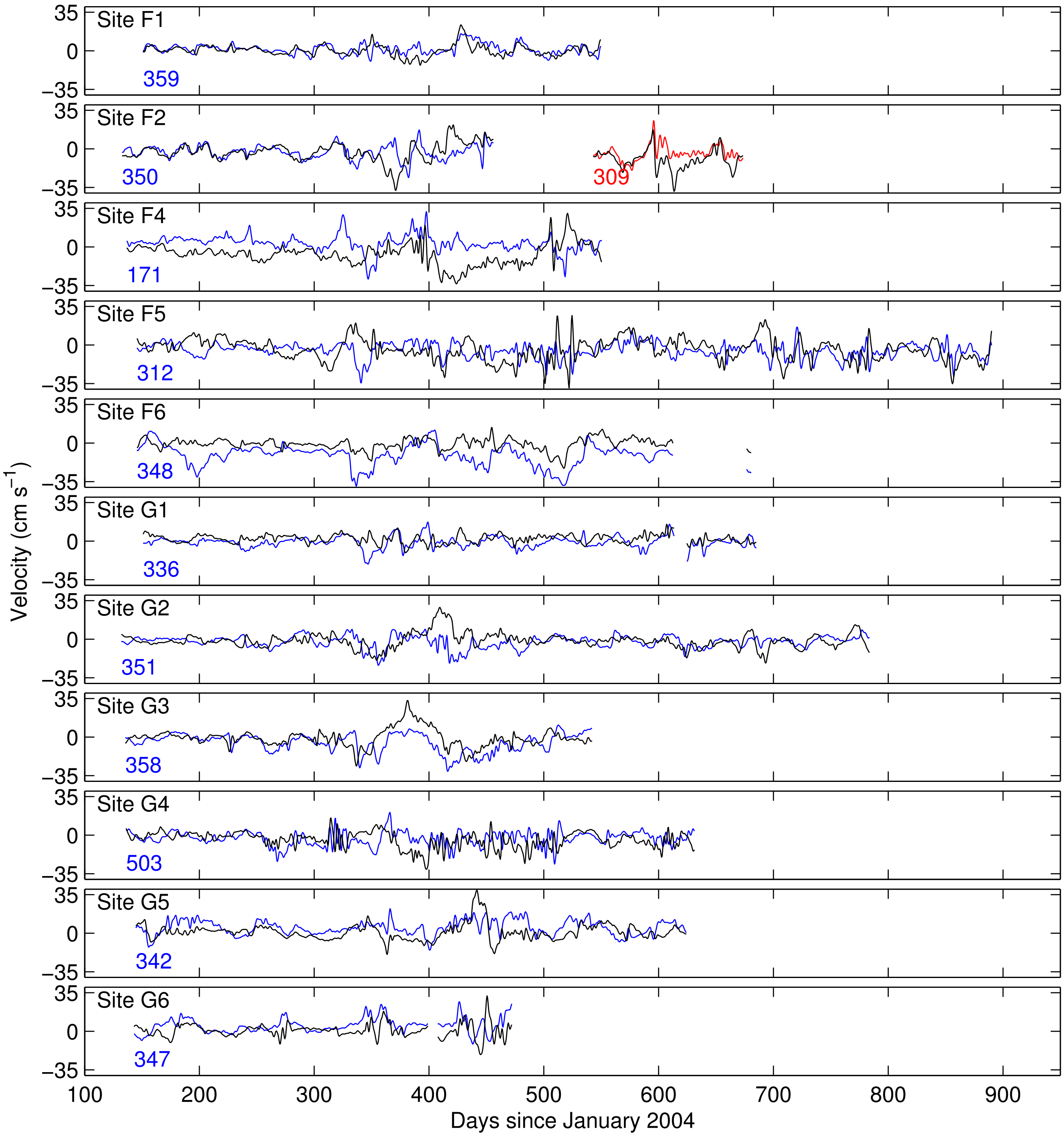


Figure 29: Time series of 72 hr lowpass filtered currents (lines F-G). The DCS SN is shown below the beginning of the time series. u is shown in color and v in black.

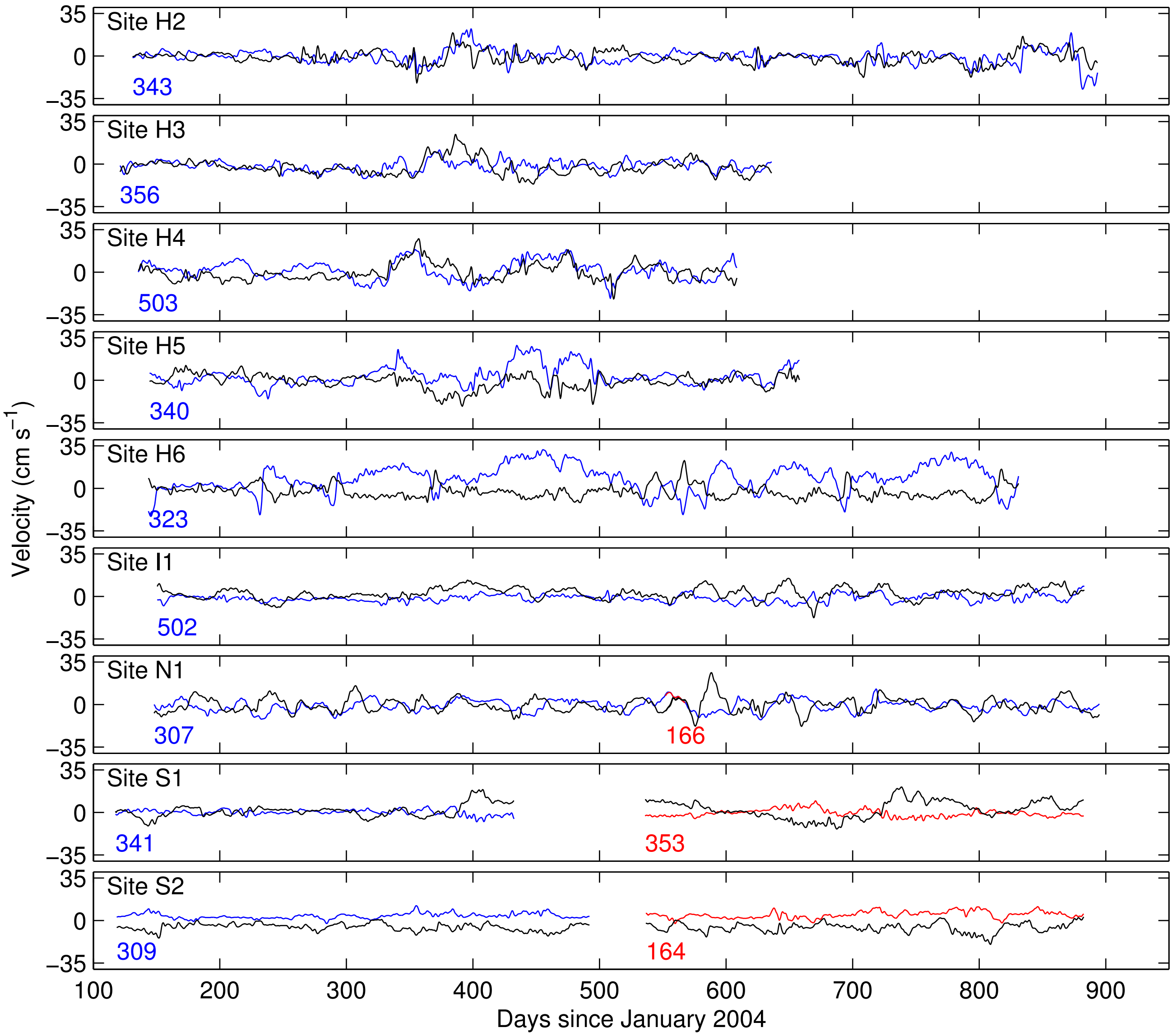


Figure 30: Time series of 72 hr lowpass filtered currents (lines H-S). The DCS SN is shown below the beginning of the time series. u is shown in color and v in black.

7 Acknowledgments

We gratefully acknowledge the crews of the R/V Thompson, R/V Revelle, and R/V Melville for their efforts during the deployment, telemetry and recovery cruises respectively. The successful deployment and recovery of the IESs is due to the instrumentation development and careful preparation done by Gerard Chaplin and Erran Sousa and by Gary Savoy and Cathy Cipolla at URI's Equipment Development Laboratory.

We appreciate the additional current meter data supplied by Dr. Nelson Hogg (WHOI) which were used to dedrift and level the bottom pressure measurements.

This work was supported by the National Science Foundation, Grant Number OCE02-21008.

References

Gill, A. E. (1982), *Atmosphere-Ocean Dynamics*, Academic Press.

Godin, G. (2007), *The analysis of tides*, University of Toronto Press.

Hogg, N. G., and D. E. Frye (2007), Performance of a new generation of acoustic current meters, *J. Phys. Oceanogr.*, *37*(2), 148–161, doi:10.1175/JPO303.1.

Kennelly, M. A., K. L. Tracey, and D. R. Watts (2007), Inverted echo sounder data processing manual, *GSO Technical Report 2007-02*, University of Rhode Island.

Munk, W. H., and D. E. Cartwright (1966), Tidal spectroscopy and prediction, *Phil. Trans. Roy. Soc. London*, *259*, 533–581.

Schwiderski, E. W. (1982), Global ocean tides. Part X. The fortnightly lunar tide (Mf) : atlas of tidal charts and maps, *NSWC TR 82-151*, Naval Surface Weapons Center.

URI (2002), Inverted echo sounder user's manual, IES Model 6.1E, *Tech. rep.*, University of Rhode Island.