GPS Phone Tags

A major advance in marine mammal telemetry, featuring:

- GPS quality locations
- Detailed individual dive and haulout data
- Efficient and cheap data relay via mobile phone GSM

Introduction

The use of conventional GPS to track marine mammals is very limited due to their short surfacing periods. This restriction has been overcome by the incorporating the Fastloc GPS system (Wildtrack Telemetry Systems, UK) that collects the data required for a GPS location within a fraction of second. The rate at which locations are calculated is at the control of the user, offering the possibility of attempting a location at every surfacing.

The tag also uses detailed data from wet/dry, pressure and temperature sensors to form detailed individual dive (max depth, shape, time at depth, etc) and haulout records along with temperature profiles and more synoptic summary records as in standard SMRU SRDLs. Both location and behavioral data are then stored in memory.

For species that come near shore – within GSM coverage – the entire set of data records stored in memory are relayed via the GSM mobile phone system. Visits ashore may be infrequent – up to six months of data can be stored onboard the tag – and these data may also be downloaded if the tag is retrieved. GSM data-relay offers very high data bandwidth and is over one hundred times more energy efficient than Argos – all for the cost of a couple of hours of phone calls!

The tag works on all international GSM frequencies. Please tell us about your application and we can discuss how the Series 9000 GPS Fastloc/GSM tag can be configured to your needs.

Physical Characteristics

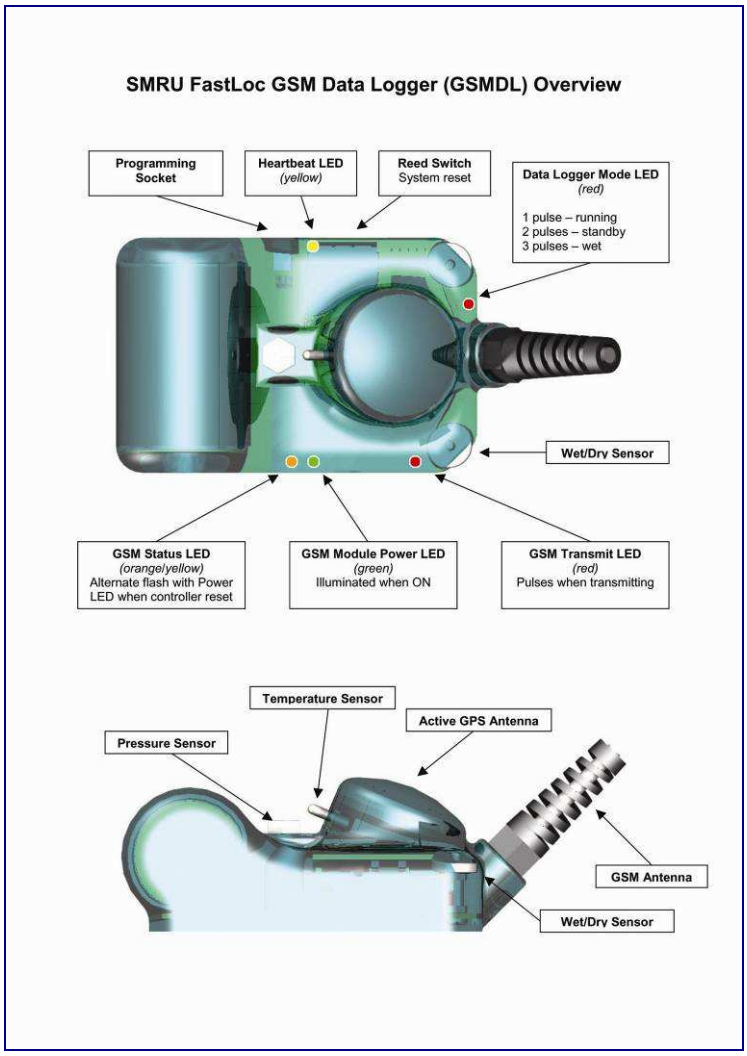
Housing:
- Solid epoxy body, rated to 500m (reinforced 2000m)

Standard sensors:
- Pressure (resolution 5m @ 2000m, 0.5m @ surface)
- Wet/dry saltwater switch
- Real-time clock
- Temperature (resolution 0.1 ^{o}C)

GSM engine:
- Siemens MC55/56 modem.
- All four GSM bands available

Longevity:
- 6 months at default parameter settings
- Shelf life of over 3 years

Dimensions (max):
- 100 x 70 x 40 (height) mm



Operation

Most of the operating parameters may be readily changed. For illustration we show [in square brackets] the default values.

GPS Fastloc Locations

Traditionally, the use of GPS to track most marine mammals at sea has been impractical due to their brief surfacing intervals and thus insufficient time to reliably gather GPS ephemeris data. The Fastloc system (http://www.wildtracker.com/prod01.htm) overcomes this problem by splitting the GPS location determination into to separate phases. A snapshot (< 0.2 s) of satellite data is captured and the pseudo-ranges are calculated on board and stored. After these pseudo-ranges are relayed ashore, they are combined with publicly available archived ephemeris information to compute locations.

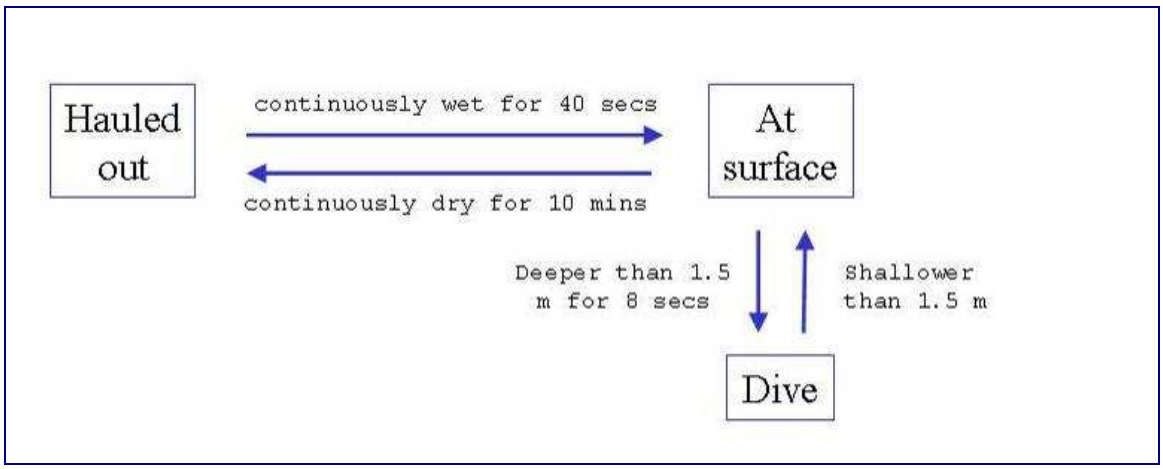
By default the tag attempts to capture location data every [20] minutes. The attempt is delayed if the seal is underwater. When the tag is in a haulout state the rate of attempts is reduced. The rate of location attempts affects the energy drawn from the battery and thus the tag longevity.

Data Sampling

Samples of depth and temperature are recorded every 4 seconds. Each tag contains its own specific calibration information, which allows it to immediately convert its sensor readings into real-world units (metres, degrees Centigrade etc). Depth is automatically reset to zero whenever the wet-dry sensor detects the surface. Rapid sampling [0.5 sec] of the wet-dry sensor is instigated when approaching the surface [6 metres].

Behavioural States

The tag continually monitors the sensor data it is collecting and maintains a three-state model of the animal's activity, determined from surface sensor/depth sensor/ time interactions.



As the tag monitors transitions from one state to another, data records of two complementary types are constructed and made available for transmission.

Data Types

Dive Record

Constructed at the end of each dive. When a dive begins, all the samples are accumulated at until the end of the dive is detected, creating a full-resolution dive profile. The tag then calculates the [9] internal points in the profile that give the best fit to the entire profile. Dives are transmitted in groups of consecutive dives. The timestamp refers to the most recent one – previous dives are positioned in time using the dive duration and surface duration fields. All other fields are optional. A post-dive surface duration exceeds [9] minutes, a termed a Cruise.

```
Time of start of last dive (required)
Dive Number
for each dive:
      Maximum depth
      Dive duration (required)
      Post-dive surface duration (required)
      Mean speed
      Dive index (%)
      Inflection points:
            Profile depth values
            Profile temperature values
            Profile speed values
            Residual of profile fit
```

Haulout Record

Constructed at the end of each Haulout. Haulout (and Cruise) records simply contain the start- and end-times of unbroken periods spent in the "Hauled Out" (or "At Surface") states. These records require only a few bits to transmit but can account for long periods of the total data record.

```
Haulout Start (date-time)
Haulout End (end-time)
Haulout number (sequence, cycling 1 through 32)
```

Summary Record

Constructed for every [2] hours This contains summary statistics such as the proportion of time spent in each of the three states; the number of dives; mean, maximum and standard deviation of maximum dive depth; mean, maximum and standard-deviation of dive duration.

```
Summary period start (date-time)
% time in state Dive
% time in state Haulout
% time in state At Surface
Maximum depth
```

Temperature Cast Records.

If a dive is one of the [2] deepest dives in each [2] hour period, the tag monitors the depth during the central phase and then collects temperature data at [1] second intervals on the ascent. Filtering and compression is performed by the conventional broken-stick method used for XBT casts, producing [12] temperature-depth pairs.

GSM Data Relay

Every [6] hours the tag will attempt to register with a local GSM mobile phone service provider. GSM coverage may extend up to 20 km or more from the nearest GSM base station and many parts of the World's coastline and nearshore waters are covered (see http://www.gsmworld.com/roaming/gsminfo/index.shtml). If the tag registers successfully a GPRS session is established and data are FTPd to a server at SMRU, St Andrews. These data are then decoded and made available for the user. Following successful data transfer the tag will delay a further attempt to register for [48] hours. Diagnostic SMS text messages are also sent.

Normally we incorporate a Vodafone SIM, and this will allow international roaming. If the attempt to register is unsuccessful, perhaps because the seal being far out to sea, data will accumulate in the internal memory until the next successful registration. Data can be stored on board for up to six months.

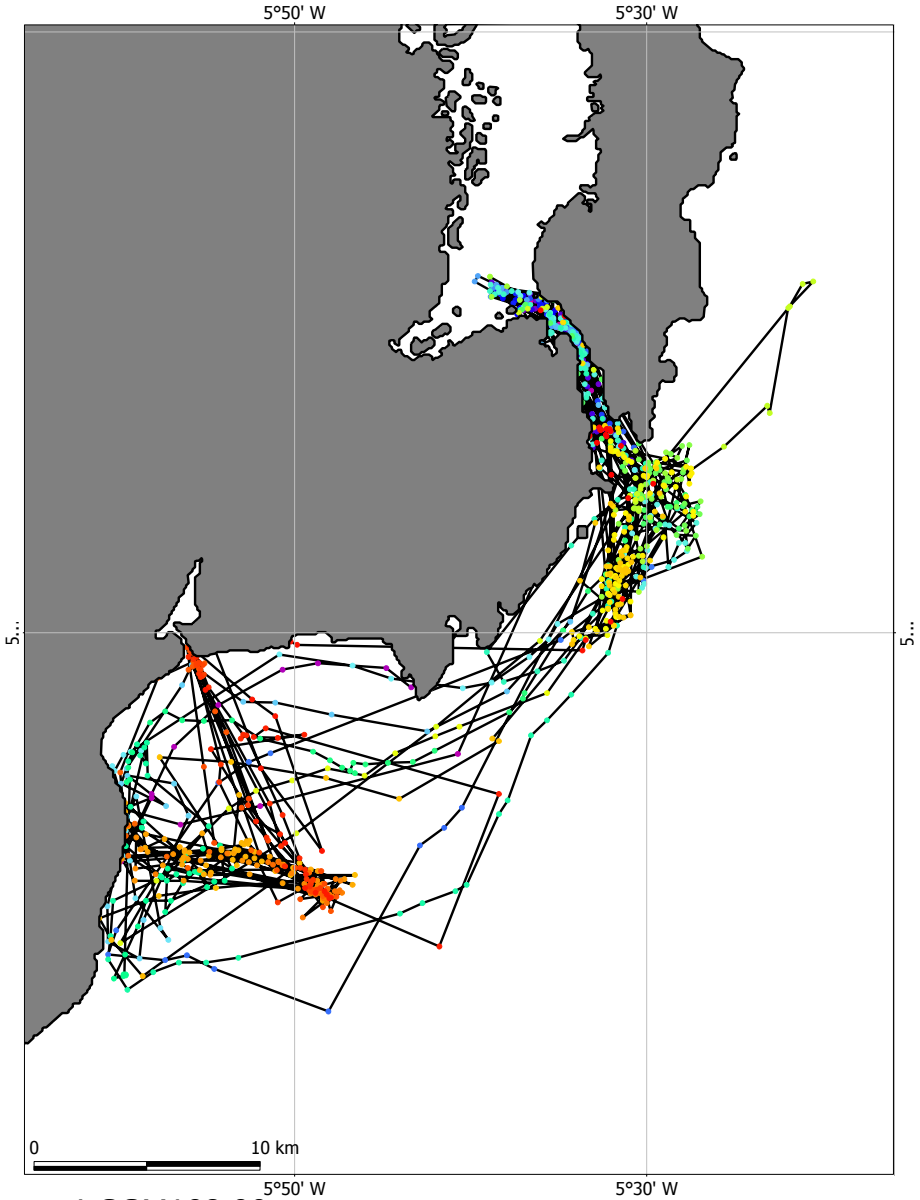
Using GSM to relay data ashore is far more efficient, allows higher bandwidth, and is much cheaper than the Argos system. However, if a seal travels far out to sea, the user must be patient and wait for the seal's return to get a data update!

Example Data

The best way to demonstrate the power of the GPS/GSM tag is to provide a sample of data. The following figures illustrate data collected by SMRU from a harbour seal (*Phoca vitulina*) in Northern Ireland. Normally user data may be viewed in near real time using the secure SMRU web server. Users can also download complete data sets in the form of an Access 200 database.

Locations

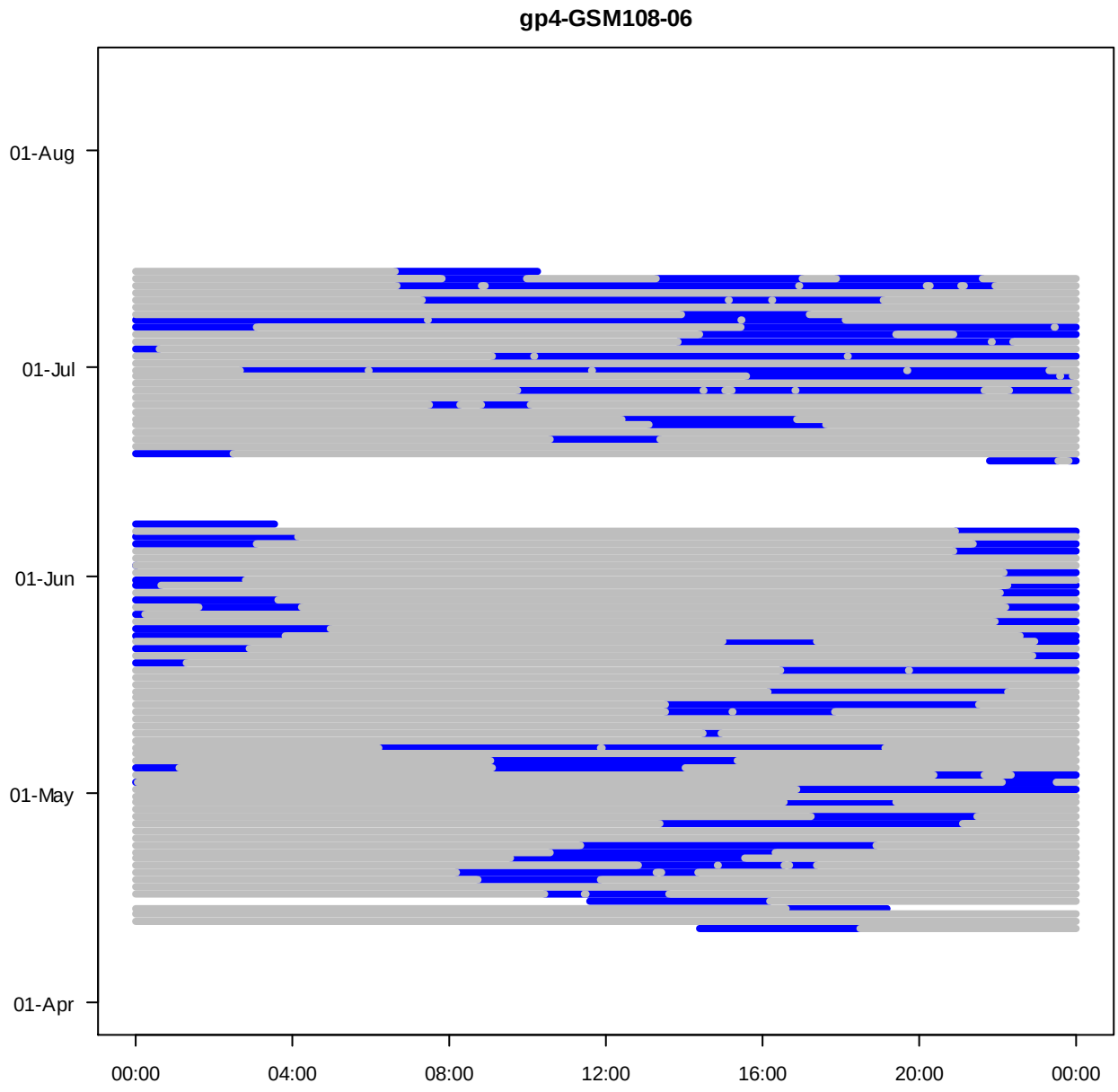
Seal gp4-GSM108-06 tracked for 95 days, producing an average of 21 locations per day. The locations are colour-coded through time. Note the 10 km scale bar.



gp4-GSM108-06

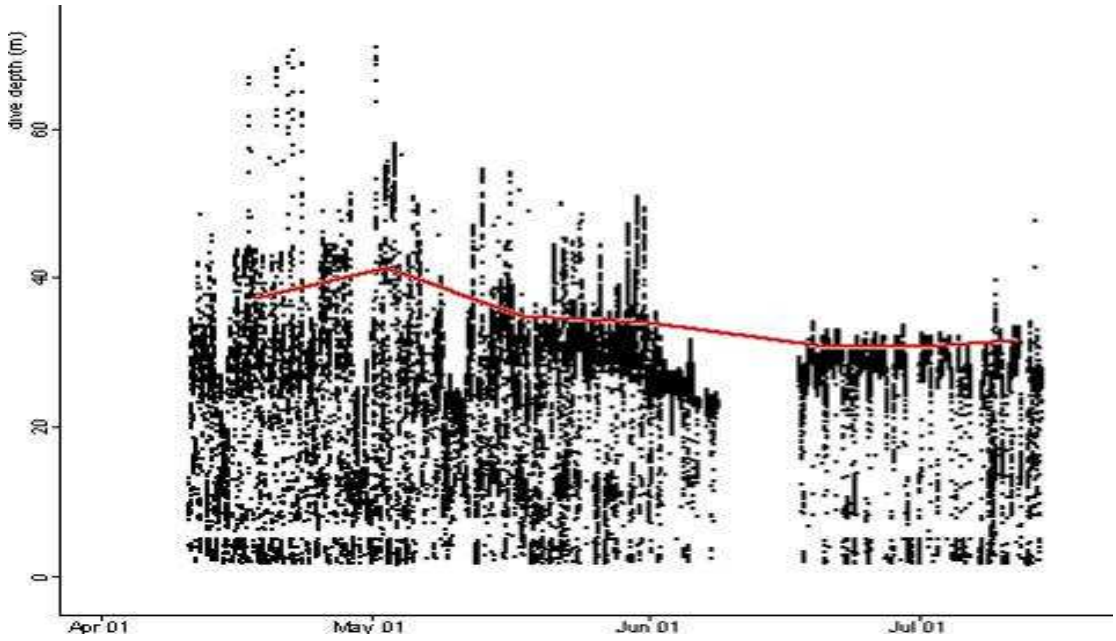
Haulout records

Individual; haulout records (blue) are show below. The x-axis is time of day. There is a gap in the data in mid June.

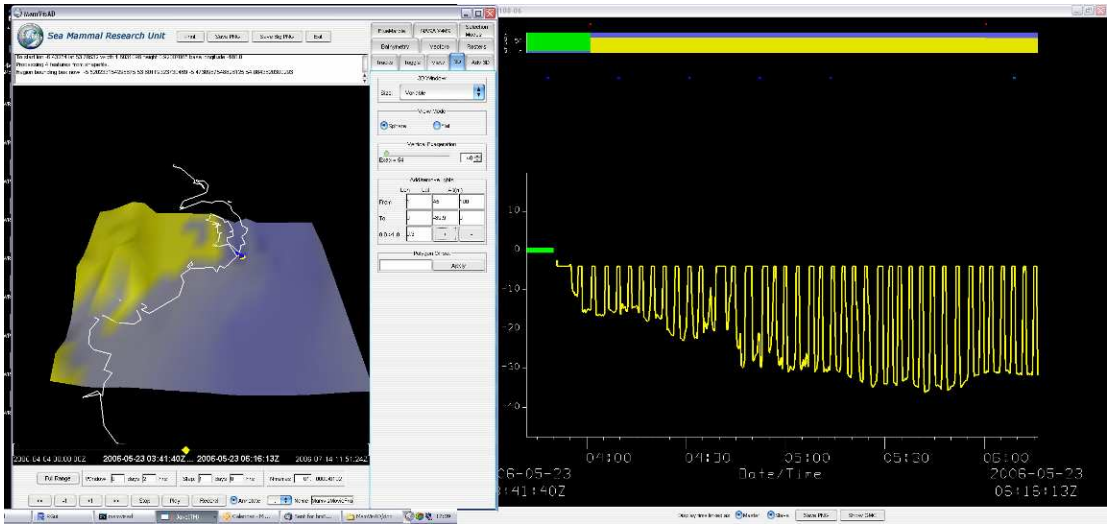


Dive data

Individual dive data. There is a gap in the data in mid June. The red line indicates the 95% quantile (15 day bin) of dive maximum depth.



MamVisAD is a 3D animation package, specially developed by SMRU (and freely available) to visualise SMRU tag data. Here we see a portion of the seal's track (left) and the corresponding dive profiles (right) following a haulout.



The Instrumentation Group

The Instrumentation Group within the Sea Mammal Research Unit comprises biologists, software and hardware engineers who work together at all levels - from the biological objectives of the study through to formulating hardware and software solutions. We have produced a number of important innovations in this field and, because we see our main role as furthering advances in knowledge, we try to make these innovations available to a wider community as quickly as possible.

We consider those who use our equipment as "collaborators" rather than "customers" and work with them to help tune the technological approach to their particular questions and to use our experience to help interpret the data.

We design and build equipment. Working with the user, we create data collection software, we decode and archive the data and make it available for distribution. We also provide a basic data visualization tool (MamVisAD) to help visualize the data. When investigators think it is helpful, we can play a role in helping with analysis.

We place an extremely high value on feedback on how devices are deployed, how effective they are thought to be and on suggestions for changes. This feedback is crucial in fostering new developments and approaches.