# Optimizing data output versus power consumption using "ACC informed GPS schedule"

## Introduction

On certain e-obs data loggers you have the possibility to optimize data output versus power consumption by coupling the GPS schedule to the accelerometer-activity of the animal with the "ACC-informed GPS schedule". This allows you to improve the efficiency of your data collection in two ways. First, you can avoid consuming power for GPS fixes when the animal is sleeping or moving only little (GPS low resolution mode). This will not only reduce the data collected on an animal that is not moving, but will be especially useful for animals who rest in holes or other hiding places where GPS fixes are impossible. Second, you can increase the temporal frequency of GPS fixes when an animal is moving. We provide two movement options which we expect will be used for typical movement (GPS medium resolution mode) and another for when the animal is moving rapidly (GPS high resolution mode).

For this function to work well, a tag must have an ACC schedule that is more frequent than typical GPS schedules. Because the ACC uses little battery, most of our customers collect readings at intervals of a few minutes, but GPS fixes at longer intervals.

**Species-specific settings:** Each species moves differently, requiring customization to set the accelerometer thresholds that tell the GPS to switch between low, medium and high temporal resolution. Please read the following carefully and try to understand. In case of questions please contact wolfgang@e-obs.de.

We are still learning the ways in which animals vary in how their movement is recorded by accelerometers. For example, in addition to differences between species, young and lighter animal may even have different ACC readings than an older, heavier animal from the same species. In addition, the accelerometer may be mounted slightly differently in different models of e-obs data loggers (e.g. collar vs. backpack). Thus, it is critical to run tests in the field to measure the typical accelerometer readings recorded by your target species before setting the threshold values for the ACC informed GPS schedule.

## Definition of ACC Variance

The "ACC informed GPS schedule" works with the variance of acceleration, which are calculated onboard the e-obs data loggers and then used to select between the three GPS resolutions (read about the algorithm for the resolution decision in a different section). Basically, the more an animal moves, the higher the variance in the ACC value over a given burst of measurements. Many users may use standard deviation as a measure of activity. This is valid, but difficult to calculate on-board the e-obs tags (square root calculation would need a lot of computing power), so we stick with variance which we define as[1]:

$$Var_{acc} = \frac{1}{N}\sum_{k=1}^{N}(a_k - \bar{a})^2 \quad \text{whereas the arithmetic mean} \quad \bar{a} \quad \text{is defined as} \quad \bar{a} = \frac{1}{N}\sum_{k=1}^{N} a_k \quad .$$

The $a_k$ are the $N$ raw acceleration values from one axis recorded on the data logger with $1 \le k \le N$ ("raw" means that these values are the raw readings coming from the Analogue-Digital-

1 The exact name for this formula is *population variance*, which is different from *sample variance*. Another name for the population variance is *second central moment*.

Converter, without being transformed to a physical meaningful dimension measured in $m/s^2$. Please read the application note so that you understand what this means).

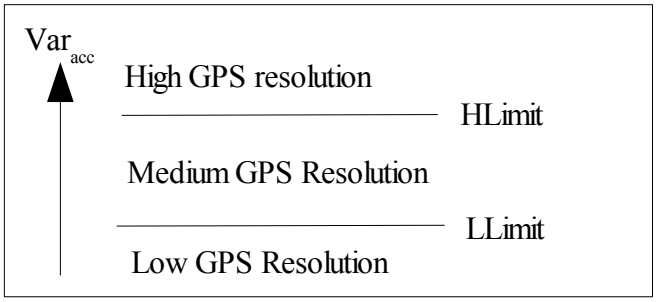
We focus just only the variance of ACC measures in one axis. Typically, the three axes record similar patterns so which one you choose is not critical, but we generally recommend the axis that varies most between resting, slow movement, and fast movement. In the configuration menu of the e-obs data logger you have to choose what axis you want to use for the variance.

Also remember that we offer two sensitivity settings on the accelerometer, which must be held constant when testing and setting the thresholds for the ACC informed GPS schedule.

## Setting of ACC Variance Thresholds

Once you have collected some preliminary data on your target species you need to decide at which point you want the GPS to switch between sample intensity. These thresholds will be used to tell the GPS to switch between high, medium and low resolution mode.

You can set two thresholds: The lower threshold (ACC_L_THR (old: acc_Llimit)) and the higher threshold (ACC_H_THR (old: acc_hlimit)). The data logger will use the thresholds as depicted in the following simplified drawing:




The actual algorithm how the different GPS resolutions are selected is more complicated (please see the flow chart). As already explained in the introduction, every animal is different. This means that you have to do a field test to find out the best variance thresholds for your project. This field test is explained in the next section.

Following is a complete list of all necessary parameters in the tag setup menu:

- `GPS HIGH RES INTERVAL`: GPS interval for high GPS resolution
- `GPS MED RES INTERVAL`: GPS interval for medium GPS resolution
- `GPS LOW RES INTERVAL`: GPS interval for low GPS resolution
- `ACC_L_THR (old: acc_llimit)`: lower threshold
- `ACC_H_THR (old: acc_hlimit)`: higher threshold
- `acc_n1`: See more detailed explanation below.
- `acc_n2`: See more detailed explanation below.
- `acc_n4`: See more detailed explanation below.
- `Axis for Var`: This selects the axis to be used for the variance.

## Setting the time thresholds

Once you have set the ACC value thresholds you need to set the temporal thresholds. These set how often a ACC threshold should be broken before the GPS schedule is switched. This will help avoid the schedule from changing with a short movement of a resting animal (e.g. scratching its

collar), or a short rest of a mostly moving animal (e.g., stop to catch its breath).

These time thresholds are parameters n1, n2 and n4. These are set in terms of the number of consecutive times a threshold is passed in a given number of ACC bursts. Parameter n1 is the setting to jump from medium to low, n2 is from low to medium, and n4 is from high back to medium. Note that there is no way to change the setting from medium up to high, because these are expected to be short-lived activities you wouldn't want to wait long to trigger the faster GPS schedule. Please see the flow chart to understand the exact and complete meaning of the different parameters. For example for parameter n2 you can see that only when the variance is higher than the lower threshold for at least n2 consecutive ACC bursts, then the GPS resolution is increased to medium resolution if the resolution before was low.
It is important to understand that this "time threshold" is not specified in "seconds" or "minutes" etc. Instead it is specified in the number of ACC bursts. The maximum for n1, n2 or n4 is 8, minimum is 0.

# Running a field test to determine the variance thresholds and other parameters

## *General aspects*

Five parameters have to be set correctly:

- What axis should be used for the variance (X, Y, or Z)?
- Set the ACC sensitivity (high or low)
- What variance thresholds should be used (acc_L_thres, acc_H_thres) (old: acc_hlimit, acc_llimit)?
- What time thresholds should be used (acc_n1, acc_n2 and acc_n4, specified in number of ACC bursts)?
- What GPS interval should be used for high, medium and low resolution?

Axis:
In many cases the z-axis is most suitable for differentiating if the animal is moving fast or not. But you can record all three axes in the field test to find out what axis is the most suitable.

Sensitivity:
It is also important to remember later if you use high or low ACC sensitivity in the field test, because the variance is calculated from the raw values. High sensitivity results in different raw values (thus in a different variance) than low sensitivity. You should later use the same sensitivity for "ACC informed GPS schedule". Many animals work fine with high sensitivity, but we have found that some species max-out the values too frequently, especially flying animals, and thus have enabled a low-sensitivity to better capture their range of values.

Thresholds:
After the first field tests, download the data from the animal, extract it using the data decoder and plot the data and calculate the variances using your favorite software (e.g. using the VARP command in Excel or Open Office Spread sheet) for every ACC burst (Note – do not use the data decoder option "Acceleration data reduced to one average and one stddev value after hp filter", because it modifies the data with a high passfilter). At this point it is time for you to consider the biology of your species and the specific scientific questions are are interested to decide which conditions you are willing to sacrifice GPS attempts for battery savings, and which conditions you would like more frequent GPS locations. Choose the acceleration variance thresholds accordingly to

get the wanted relation between GPS resolution and acceleration activity.

After this test you need to set both the variance thresholds and the temporal GPS schedules associated with them in the tag setup menu. For example, here are these values used for Fishers (Martes pennanti):

| | **ACC Variance Threshold** | **GPS Schedule** |
|---|---|---|
| **Low** | <80 | 6hr |
| **Medium** | 80-220 | 15min |
| **High** | >220 | 2min (recommended no lower than 2min)[2] |

| | Temporal thresholds |
|---|---|
| n1 | 5 |
| n2 | 2 |
| n4 | 4 |

**GPS resolution**
When setting the low, medium and high GPS temporal resolutions you should consider aspects of how fast your animal moves, how quickly the GPS is able to get a fix, and what your required battery time is.
We envision the lowest resolution being used when an animal is sleeping, In this case there is no movement so obtaining frequent fixes is a waste of battery power. Additionally, many animals rest in places where no GPS fix is possible (e.g. in a hole), meaning the tag would simply be wasting battery power. Having this function enabled may also allow you to increase the search-time settings on your tag to obtain more successful fixes when the animal is moving through forested areas. Consider the length of resting bouts for your animal. We expect schedules of one fix every 3-6hrs will be sufficient for most species.
We envision the medium resolution being useful for typical movements of animals. Consider how fast the species changes position and how frequently you would need to record it. We expect intervals of 10-60min to be typical of this setting.
We envision the high resolution settings for cases where the animal is moving rapidly, or doing some other high-activity behaviors of great interest. We expect intervals of 2-15min to be typical of this setting. If your animal never moves rapidly you may choose not to implement this schedule (set the medium and high GPS schedules to be the same).

## *Performing the field test in detail*

Only after the first field tests you will know the suitable thresholds. This means that in most cases for the first field tests it doesn't make sense to use the variance feature and thus you should disable the variance feature by using the same GPS interval for all resolutions (low, medium and high resolution). Maybe you also don't want to waste battery power for GPS, then you also should disable GPS for the field test. But then you are maybe not able to find the relation between acceleration variance and GPS fixes if you don't observe the animal.

2 In case you need higher resolution: Use the GPS burst mode! For example every 5 minutes you can record 20 positions at a rate of one position per second.

# FAQ

1. Will the thresholds affect the frequency of the ACC recordings?

No. Once you set the ACC schedule in the collar it will run at that interval until the collar is manually reprogrammed. This ACC-informed GPS schedule only affects the GPS schedule.

2. Will the low-resolution GPS schedule give lower-accuracy locations?

No. the low 'resolution' only refers to the temporal resolution, the frequency in which the collar attempts to get a fix. However, there are times where multiple fixes from a stationary animal could be averaged to obtain a more accurate location. This is post-processing of data that you could do on your own, and is not common as far as we know of.

3. Won't irregular fix intervals screw up my data analysis?

It might. Some analyses require data at regular intervals. The unavoidable missing of occasional GPS fixes makes this a concern with any GPS schedule. The purposeful changing of GPS schedules makes this potentially a larger problem. There are methods to mimic a regular schedule of data collection by inventing regular time-steps with no data which meet the regular-interval assumptions of some analyses. We leave the data-analysis responsibilities to the end-user, but have noted these types of functions in some analysis packages (e.g. ADEhabitat packge for R, commands: is.regular, setNA, sett0 ). Please consider this aspect of your project carefully before using the ACC-informed GPS schedule option on our tags.

4. What level of performance improvement can I expect from this function?

This will depend on a variety of conditions related to where your animal sleeps, what the forest cover is like, and the schedule of your fixes. One early test with fishers found an improvement from a 45% successful fix rate to a 70% successful fix rate, lowering the average GPS search time from 84sec to 66sec.