

# Virtual Oceans: Simulating Complex Soundscapes

Generating Realistic Acoustic Data for Robust Sonar Benchmarking and Validation



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## Introduction

We simulate complex underwater soundscapes that replicate real-world variability. These are used to benchmark detection and tracking algorithms and to support sensor deployment planning.

- Generate noise from multiple ocean sources
- Inject signals for detection & tracking tests
- Quantify algorithm robustness and sensor performance

## Noise Sources

The ocean soundscape is a composite of sources, each dominating different parts of the frequency spectrum.

### Biological

Marine life sounds (e.g., shrimp, whales, dolphins).

### Anthropogenic

Human activities (e.g., commercial shipping, sonar, construction).

### Geophysical

Natural physical processes (e.g., wind-driven waves, rain, earthquakes).

#### Dominant Sources by Frequency

##### <10 Hz

Wave interactions, ship propellers

##### 10-500 Hz

Surf & storms, commercial shipping, baleen whales

##### 0.5-25 kHz

Breaking waves, mid-freq. sonar, snapping shrimp

##### >25 kHz

Thermal noise, high-freq. sonar, dolphin echolocation

## Case Study: Snapping Shrimp

### Bursty

Snapshots occur in non-independent clusters.

### Heavy-Tailed

Extreme events are more likely than in a Gaussian model.

### Impulsive

Frequent, high-amplitude clicks.

### 1. Snap Timing (When?)

A **Non-Homogeneous Poisson Process (NHPP)** with intensity function  $\lambda(t)$  models snap timing, modulated by temperature and diurnal/tidal cycles.

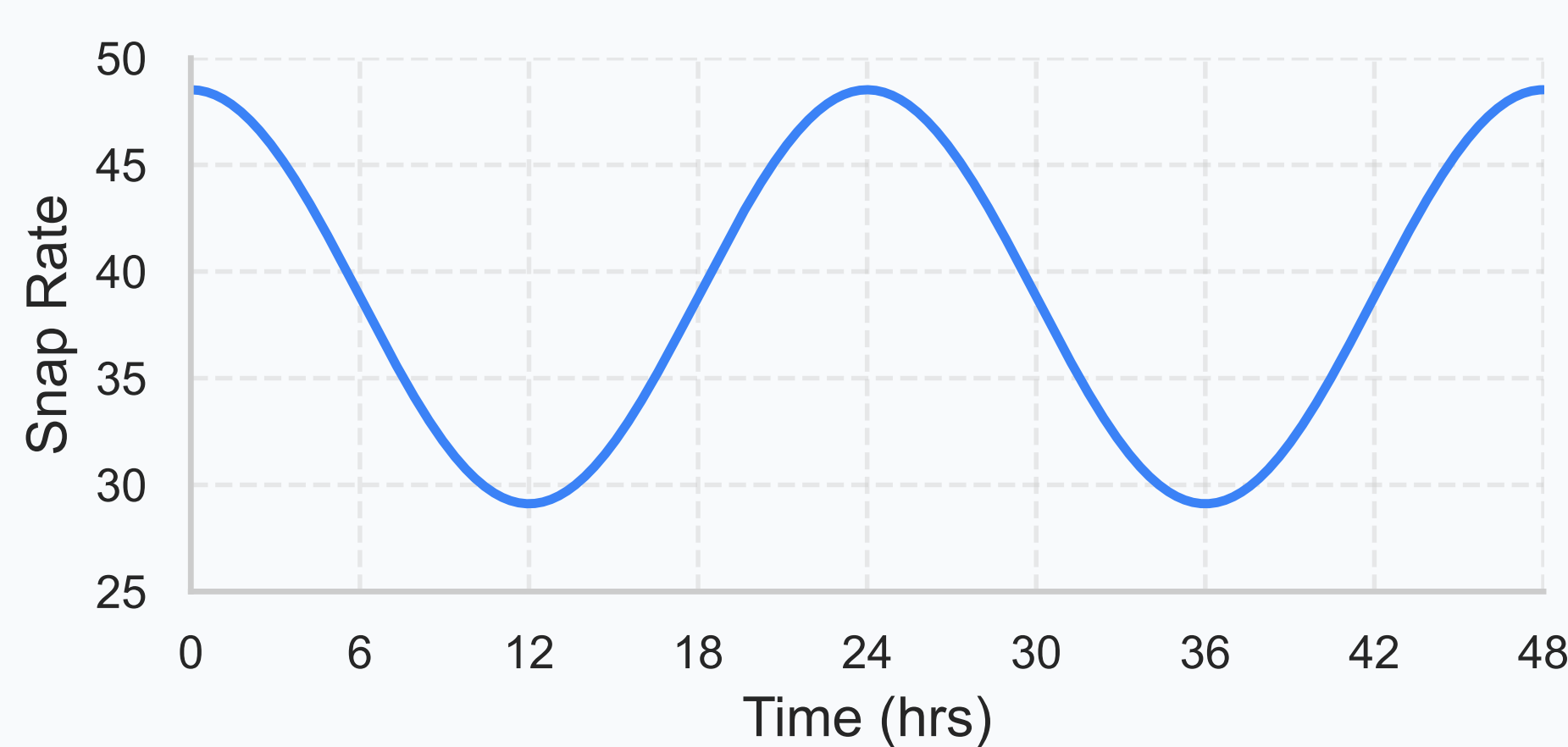


Figure 1. The diurnal cycle shows that snap rates are highest at night.

### 2. Snap Waveform (What?)

Each ~2ms snap is built using a **Modelled Waveform**, representing the acoustic signature of a collapsing cavitation bubble. This captures the sharp, broadband nature of the sound.

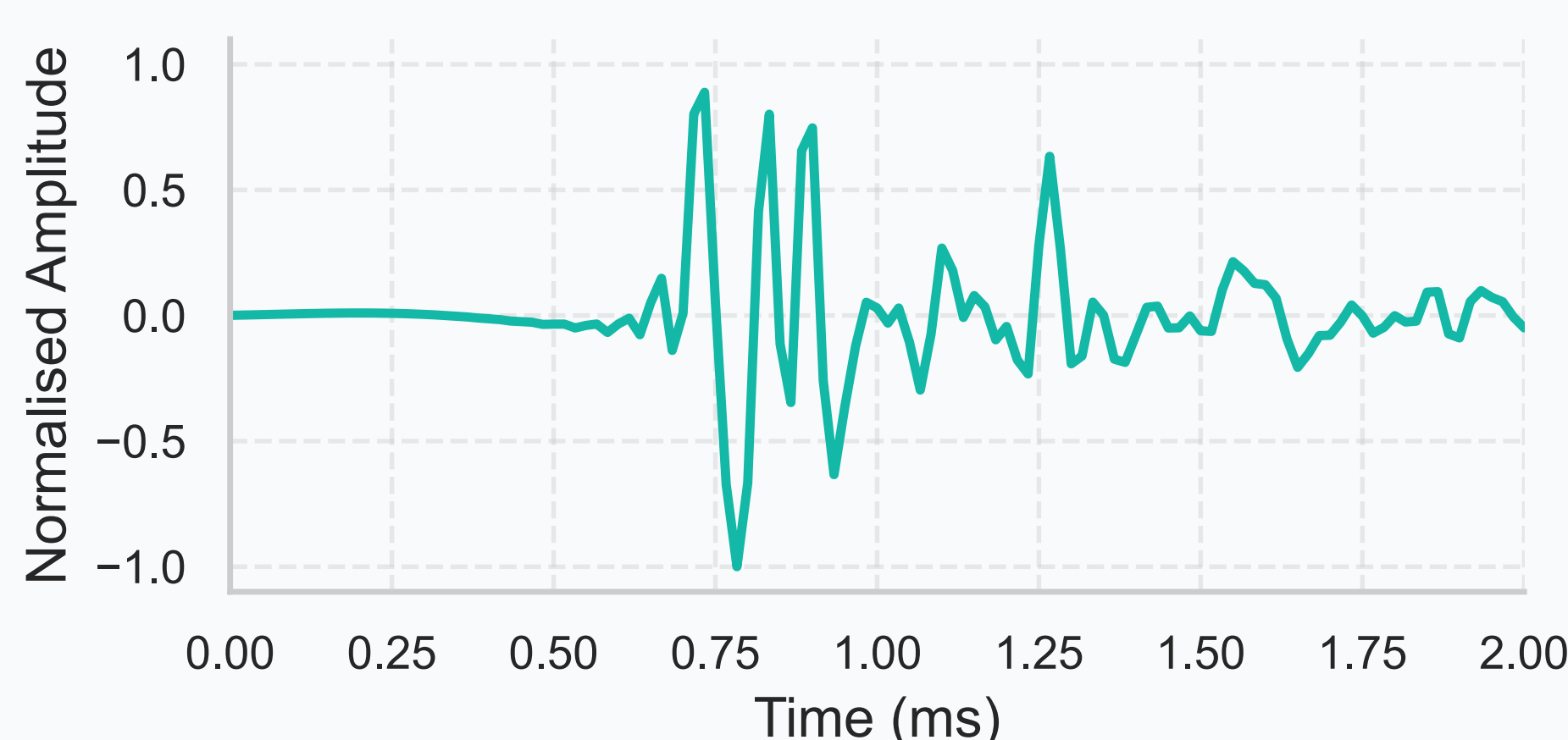


Figure 2. Modelled snap waveform (~2 ms).

### 3. Snap Amplitude (How Loud?)

Loudness is modelled with a heavy-tailed **Symmetric Alpha-Stable (SoS)** distribution. This correctly predicts the probability of the extremely loud snaps that characterise this type of noise.

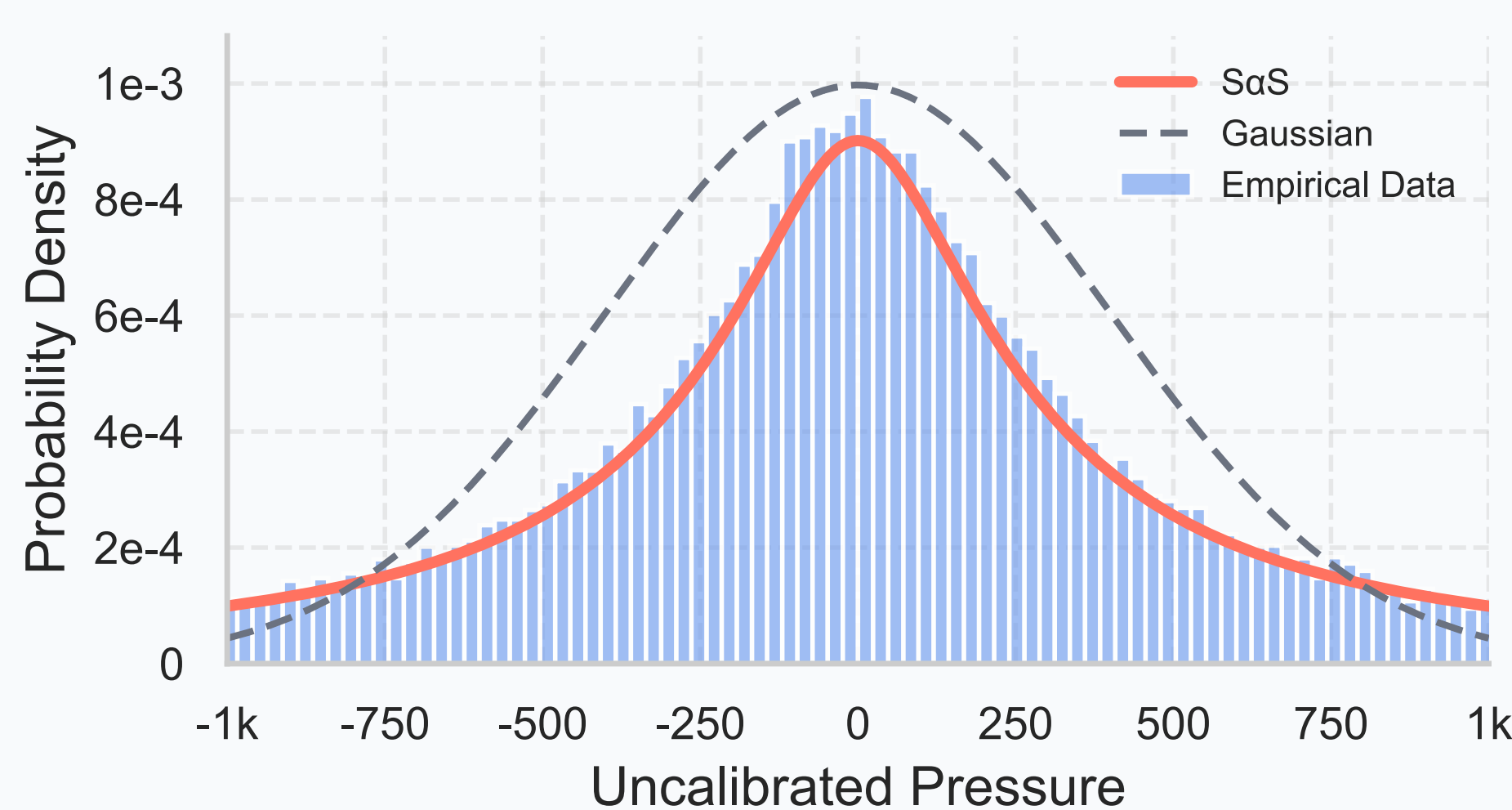


Figure 3. The SoS distribution correctly models the heavy tail of real data, unlike a traditional Gaussian model.

## Detection & Tracking

The simulated soundscape enables realistic testing of tracker performance under dynamic acoustic conditions.

### Detection

Measure probability of detection and false alarm rate as functions of SNR.

### Tracking

Evaluate localisation error, ID switches, track fragmentation and continuity under variable noise and source density.

### Operational impacts

Distant shipping reduces SNR and detection range; snapping shrimp produce clustered false positives; wind and wave noise increase background noise.

## Key Points

- **Realism:** Models reproduce empirical statistics across noise types.
- **Benchmarking:** Generates labelled acoustic datasets for algorithm validation.
- **Impact:** Informs robust tracker design and optimal sensor placement.

## More Info

Scan for audio samples, references & extra materials



<https://jjwakefield.github.io/showcase2/025poster/infographic.html>