

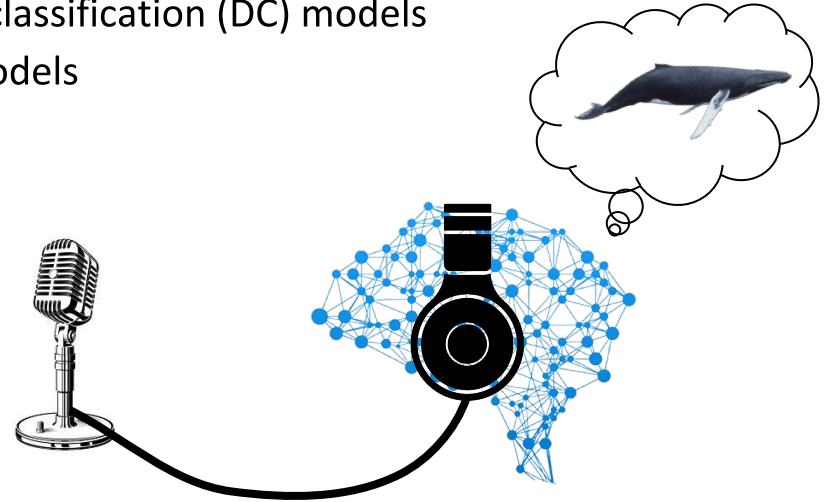
# Detecting and Classifying Underwater Sounds with Ketos

**Oliver Kirsebom**  
Fabio Frazao  
Bruno Padovese  
Stan Matwin

MERIDIAN, Institute for Big Data Analytics,  
Dalhousie University, Halifax, Canada

Deep learning can ...

- help us create better acoustic detection and classification (DC) models
- change the way we develop and use these models



# Deep learning - everyday examples



## Speech recognition/ synthesis



## Facial Recognition

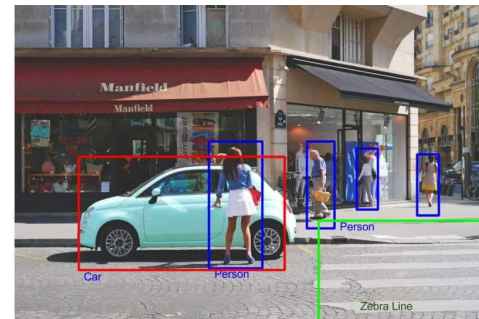


Deep Learning,  
Deep Neural Networks,  
Artificial Intelligence (AI) ...

## Translation



## Object detection



# Deep learning in marine bioacoustics



Luo et al.: JASA Express Letters <https://doi.org/10.1121/1.5085647> Published Online 4 January 2019

## Convolutional neural network for detecting odontocete echolocation clicks

Wenyu Luo, Wuyi Yang<sup>ab</sup> and Yu Zhang  
Key Laboratory of Underwater Acoustic Communication and Marine Information  
Technology of the Ministry of Education, College of Ocean and Earth Science,  
Xiamen University, Xiamen, China  
[luowenyu@stu.xmu.edu.cn](mailto:luowenyu@stu.xmu.edu.cn), [wuyiyang@xmu.edu.cn](mailto:wuyiyang@xmu.edu.cn), [yuzhang@xmu.edu.cn](mailto:yuzhang@xmu.edu.cn)

## Marine Mammal Species Classification using Convolutional Neural Networks and a Novel Acoustic Representation

Mark Thomas<sup>1</sup>, Bruce Martin<sup>2</sup>, Katie Kowarski<sup>2</sup>, Briand Gaudet<sup>2</sup>, and Stan Matwin<sup>1,3\*</sup>

SCIENTIFIC  
REPORTS  
nature research

## Deep neural networks for automated detection of marine mammal species

Yu Shiu<sup>1,2\*</sup>, K. J. Palmer<sup>2,3</sup>, Marie A. Roch<sup>1</sup>, Erica Fleishman<sup>2</sup>, Xiaobai Liu<sup>2</sup>, Eva-Marie Nosal<sup>4</sup>, Tyler Helble<sup>4</sup>, Danielle Cholewiak<sup>4</sup>, Douglas Gillespie<sup>4</sup> & Holger Klinck<sup>1</sup>

SCIENTIFIC  
REPORTS  
nature research

## ORCA-SPOT: An Automatic Killer Whale Sound Detection Toolkit Using Deep Learning

Christian Bergler<sup>1</sup>, Hendrik Schröter<sup>2</sup>, Rachael Xi Cheng<sup>3</sup>, Volker Barth<sup>1</sup>, Michael Weber<sup>1</sup>, Elmar Nöth<sup>1</sup>, Heribert Hofer<sup>2,4,5</sup> & Andreas Maier<sup>2</sup>

JASA  
ARTICLE

## Beluga whale acoustic signal classification using deep learning neural network models

Ming Zhong,<sup>1</sup> Manuel Castellote,<sup>2,3</sup> Rahul Dodhia,<sup>1</sup> Juan Lavista Ferres,<sup>1</sup> Mandy Keogh,<sup>2</sup> and Arian Brewer<sup>2</sup>

<sup>1</sup>AI for Good Research Lab, Microsoft, Redmond, Washington 98052, USA  
<sup>2</sup>Alaska Fisheries Science Center—National Oceanic and Atmospheric Administration (NOAA) Fisheries and Joint Institute for the Study of the Atmosphere and Ocean (JISAO), University of Washington, Seattle, Washington 98195, USA

## Performance of a Deep Neural Network at Detecting North Atlantic Right Whale Upcalls

Oliver S. Kirsebom,<sup>1,4</sup> Fabio Frazao,<sup>1</sup> Yvan Simard,<sup>2,3</sup> Nathalie Roy,<sup>3</sup> Stan Matwin,<sup>1,4</sup> and Samuel Girard

<sup>1</sup>Institute for Big Data Analytics, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada

<sup>2</sup>Fisheries and Oceans Canada Chair in underwater acoustics applied to ecosystem and marine mammals, Marine Sciences Institute, University of Quebec at Rimouski, Rimouski, Quebec, Canada

<sup>3</sup>Maurice Lamontagne Institute, Fisheries and Oceans Canada, Mont-Joli, Quebec, Canada

<sup>4</sup>Institute of Computer Sciences, Polish Academy of Sciences, Warsaw, Poland

SCIENTIFIC  
REPORTS  
nature research

## Deep Machine Learning Techniques for the Detection and Classification of Sperm Whale Bioacoustics

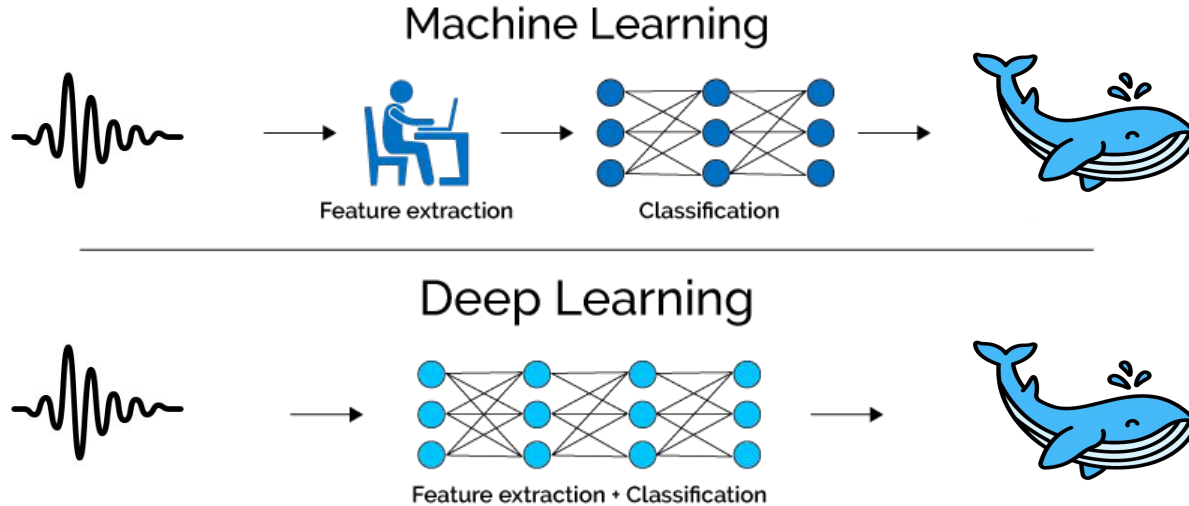
Peter C. Berman<sup>1</sup>, Michael M. Bronstein<sup>1,2,3</sup>, Robert J. Wood<sup>3,4</sup>, Shane Gero<sup>5</sup> & David F. Gruber<sup>3,4</sup>

- Deep learning works, is now a mature technique
- Outperforms conventional DC algorithms
- It's time to build tools and applications that make these algorithms accessible to marine bioacousticians

# Deep learning in a nutshell



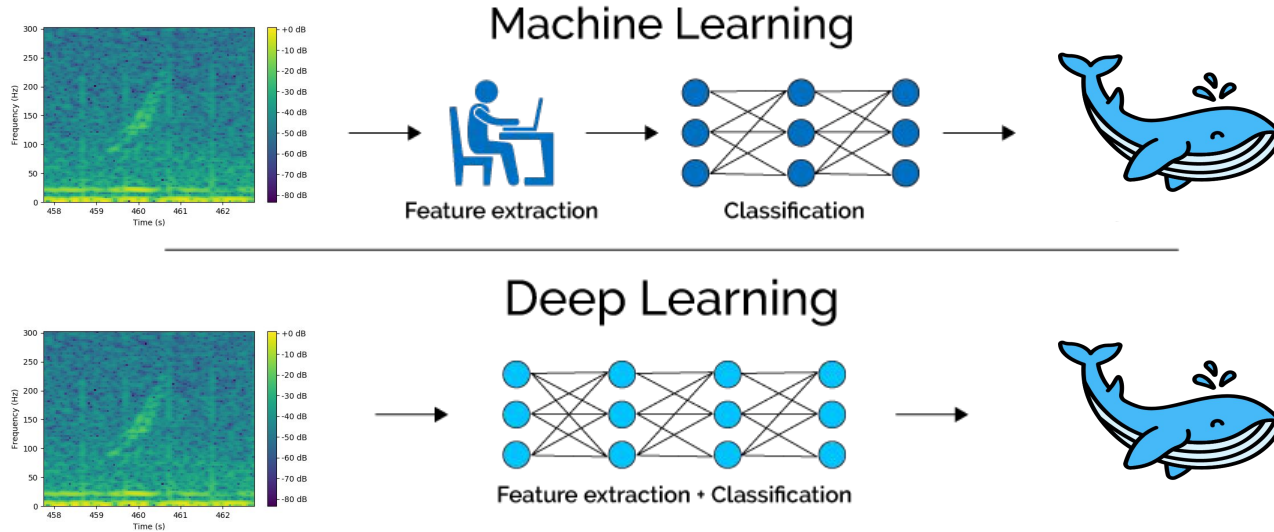
Deep Learning aims to be end-to-end (but usually isn't)



# Deep learning in a nutshell



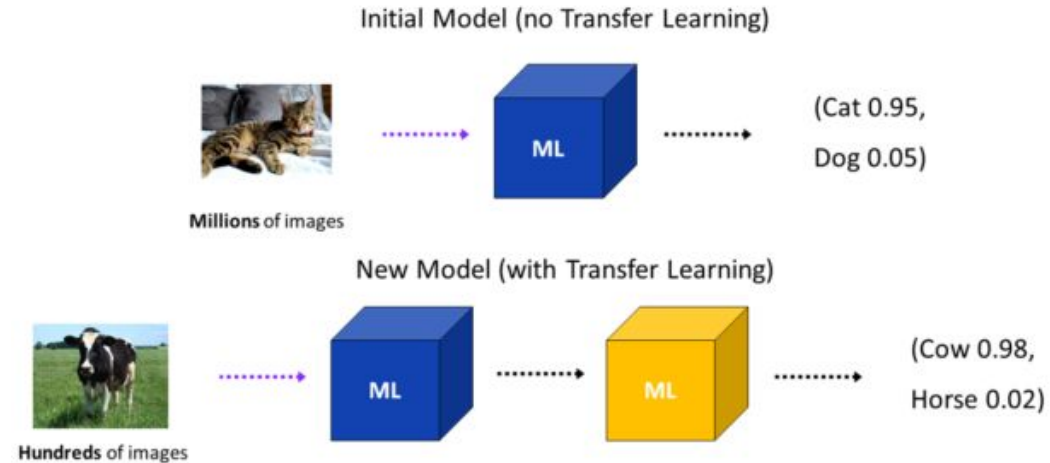
Deep Learning aims to be end-to-end (but usually isn't)



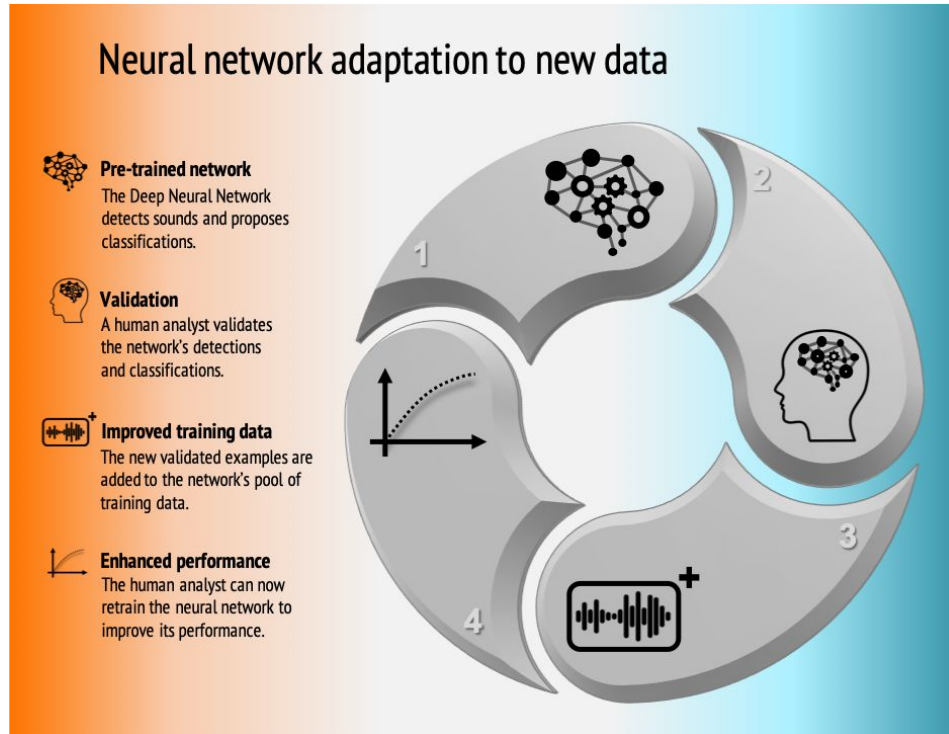
# Transfer learning (model adaptation)



- Transfer learning can ...
  - drastically reduce amount of training data and training time
  - make models more adaptable and reusable



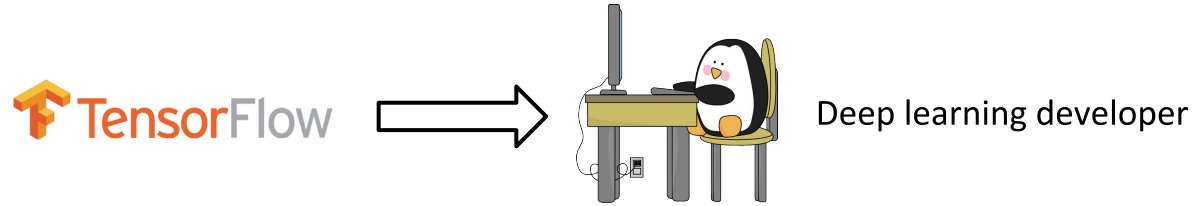
# Workflow



p. 144-145:  
"Towards Versatile and Adaptive  
Detection Algorithms in  
Underwater Acoustics"



# Making deep learning accessible



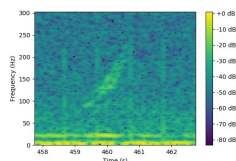


- In Ancient Greek, *ketos* denotes a large fish, whale, shark, or sea monster.
- *ketos* is also the origin of the scientific term for whales, cetacean.

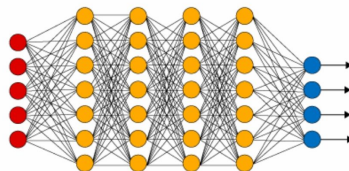
# Ketos - at a glance



Audio  
processing



Neural network  
architectures



Training  
Database

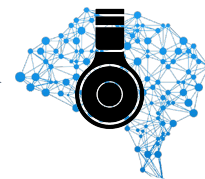
|   | A                                   | B     | C     | D   |
|---|-------------------------------------|-------|-------|-----|
| 1 | filename                            | label | start | end |
| 2 | IML-BA_Sample_2019-06-02_025209.wav | 1     | 0     | 3   |
| 3 | IML-BA_Sample_2019-06-02_065235.wav | 1     | 0     | 3   |
| 4 | IML-BA_Sample_2019-06-08_012119.wav | 1     | 0     | 3   |
| 5 | IML-BA_Sample_2019-06-21_201729.wav | 1     | 0     | 3   |
| 6 | IML-BA_Sample_2019-06-29_124902.wav | 1     | 0     | 3   |
| 7 | VAS_Sample_2019-06-06_052058.wav    | 1     | 0     | 3   |
| 8 | VAS_Sample_2019-06-06_052147.wav    | 1     | 0     | 3   |
| 9 | VAS_Sample_2019-06-06_052545.wav    | 1     | 0     | 3   |

Annotation tables



Training methods

Trained DC model



## Ketos - at a glance



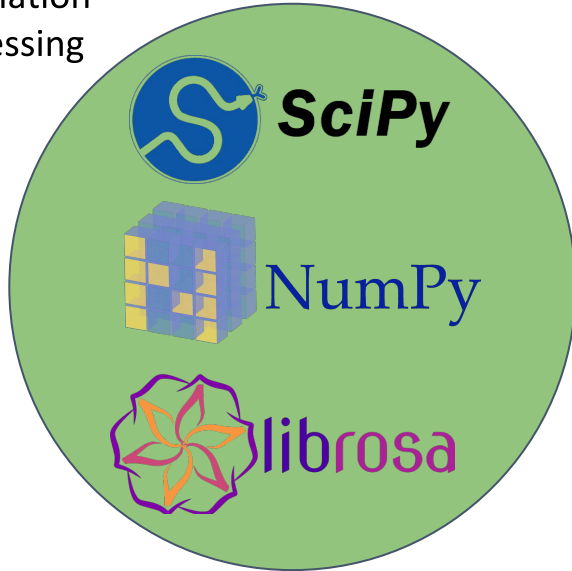
copyleft license

- Written in Python
- GNU GPLv3 license - freely available to use and modify
- Hosted on GitLab:  
[https://gitlab.meridian.cs.dal.ca/public\\_projects/ketos](https://gitlab.meridian.cs.dal.ca/public_projects/ketos)
- Fully documented code, including examples:  
<https://docs.meridian.cs.dal.ca/ketos/>
- Tutorials, version history, and more ...
- Available on the Python Package Index (PyPi) - the official third-party software repository for Python

# Open-source libraries



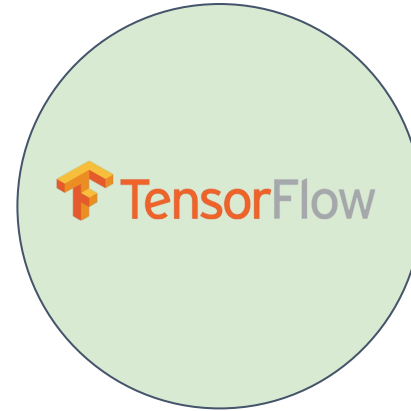
## 1. Audio data manipulation & processing



## 2. Data handling & storage



## 3. Machine learning, neural networks



# Documentation - <https://docs.meridian.cs.dal.ca/ketos/>



ketos

Underwater acoustic detection and classification with deep neural networks



2.1

- Introduction
- Installation
- Tutorials
- Modules
- How to contribute
- Versions

[Docs](#) » Welcome to Ketos's documentation!

[View page source](#)

## Welcome to Ketos's documentation!

### Introduction

Ketos provides a unified, high-level interface for working with acoustic data and deep neural networks. Its main purpose is to support the development of deep learning models for solving challenging detection and classification problems in underwater acoustics.

Ketos is written in Python and utilizes a number of powerful software packages including NumPy, HDF5, and Tensorflow. It is licensed under the [GNU GPLv3 license](#) and hence freely available for anyone to use and modify. The project is hosted on GitLab at [https://gitlab.meridian.cs.dal.ca/public\\_projects/ketos](https://gitlab.meridian.cs.dal.ca/public_projects/ketos).

Ketos was developed by the [MERIDIAN Data Analytics Team](#) at the [Institute for Big Data Analytics](#) at Dalhousie University. We are grateful to Amalis Riera and Francis Juanes at the University of Victoria, Kim Davies and Chris Taggart at Dalhousie University, and Kristen Kanes at Ocean Networks Canada for providing us with annotated acoustic data sets, which played a key role in the early phases of the project. The first version of Ketos was released in April 2019.

The intended users of Ketos are primarily researchers and data scientists working with (underwater) acoustics data. While Ketos comes with complete documentation and comprehensive step-by-step tutorials, some familiarity with Python and especially the NumPy package would be beneficial. A basic understanding of the fundamentals of machine learning and neural networks would also be an advantage.

To get started with Ketos, follow the [Installation](#) instructions and then proceed to the [Tutorials](#) section. For an example application of Ketos, see [Kirsebom, Frazao, et al., Performance of a deep neural network at detecting North Atlantic right whale upcalls, JASA, 147, 2636 \(2020\) \(preprint\)](#).

The name Ketos was chosen to highlight the package's main intended application, underwater acoustics. In Ancient Greek, the word ketos denotes a large fish, whale, shark, or sea monster. The word ketos is also the origin of the scientific term for whales, cetacean.

### Indices and tables

- [Index](#)
- [Module Index](#)
- [Search Page](#)

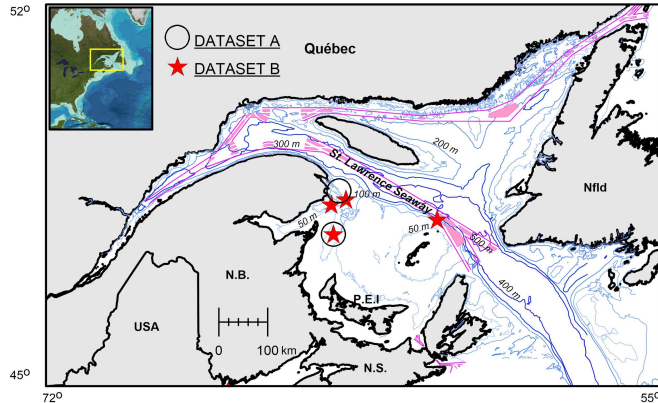
[Next](#) ➔

# Ketos example: North Atlantic right whale

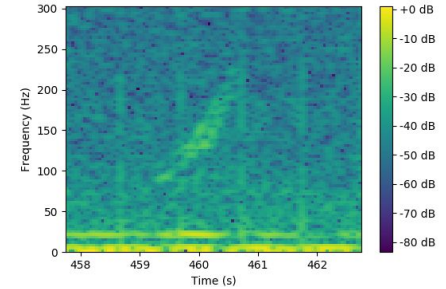
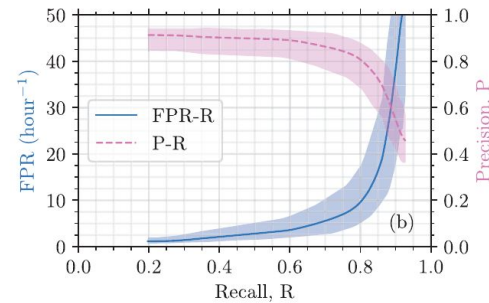
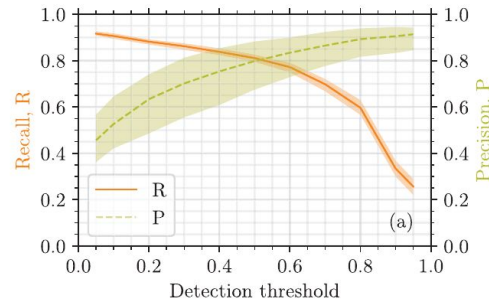


## Training and test data

- Gulf of St Lawrence & Gulf of Maine
- Surface boys and bottom moorings
- Over 5,000 NARW upcalls
- Data and annotations available at FRDR: [doi.org/10.20383/101.0241](https://doi.org/10.20383/101.0241)



Kirsebom, Frazao, *et al.* (2020) JASA **147**, 2636



Example of NARW upcall

Computer code available at Zenodo:  
[doi.org/10.5281/zenodo.3736625](https://doi.org/10.5281/zenodo.3736625)

Step-by-step tutorials at:  
[docs.meridian.cs.dal.ca/ketos/](https://docs.meridian.cs.dal.ca/ketos/)

# Summary



Deep learning can ...

- help us create better acoustic detection and classification (DC) models
- change the way we develop and use these models

Ketos ...

- is an open-source Python package for developing deep learning based acoustic detectors and classifiers
- provides neural network architectures, transfer learning capabilities, tools for dealing with larger-than-memory datasets, audio processing, saving and sharing of models, and more
- offers extensive documentation and step-by-step tutorials
- check it out at <https://docs.meridian.cs.dal.ca/ketos/>





# Funders and Partners



## Funders



## Partners





<http://meridian.cs.dal.ca>



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