The Kadlu software package

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Underwater soundscape components

Anthropo-phony

Shipping, oil and gas, naval operations, fishing, research, construction, icebreaking, recreational boating, ...

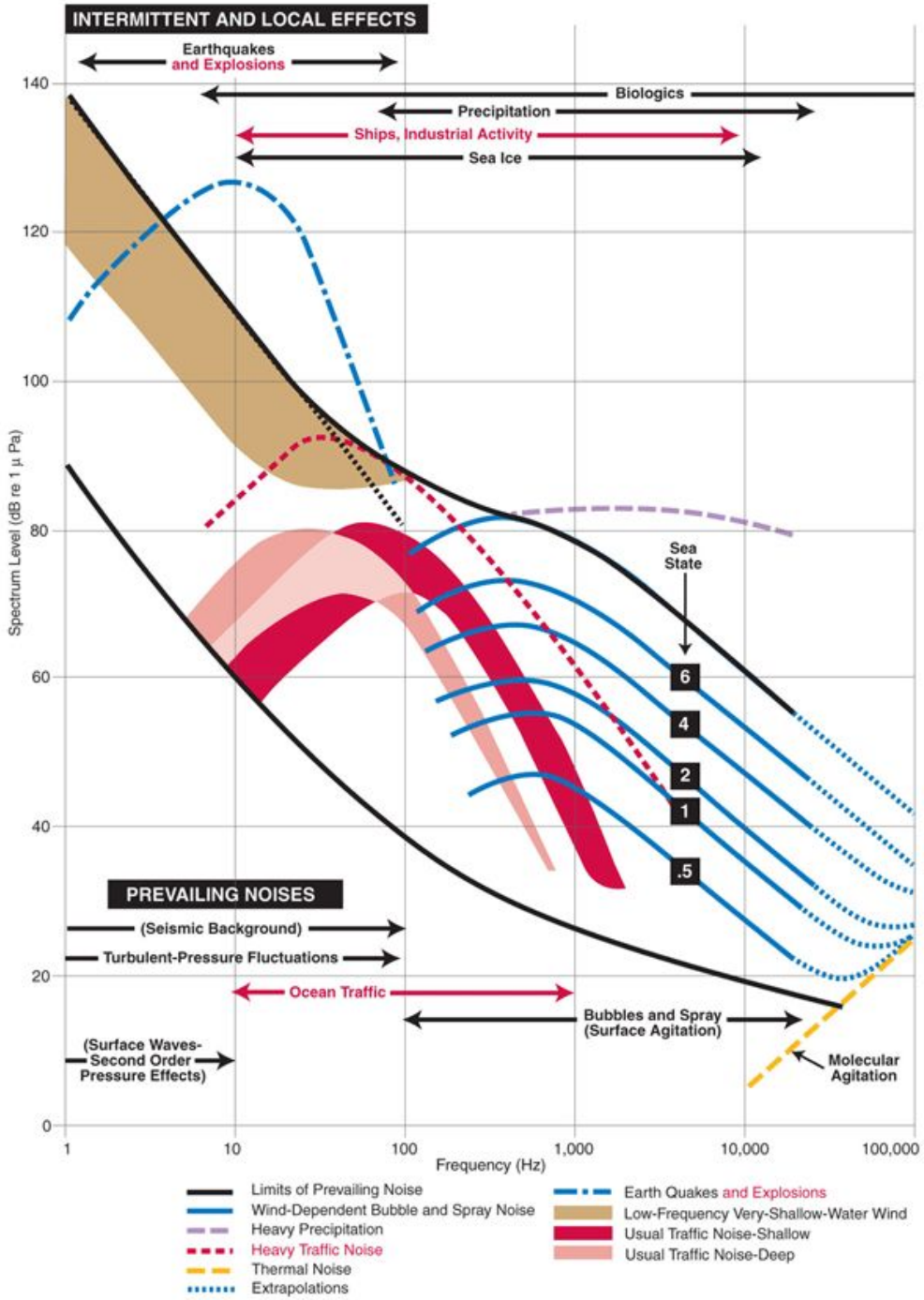
Bio-phony

Sounds produced by fish and marine mammals

Geo-phony

Earthquakes, waves, rain, thermal, ...

Photo credit: Reinhard Dirscherl/Alamy Stock Photo



Above ≃ 100 Hz, bubble/spray noise (waves) and precipitation are the major sources of ambient ocean noise.

Image credit: https://dosits.org/

Adapted (after National Research Council, 2003) from Wenz, G. M. (1962). Acoustic ambient noise in the ocean: Spectra and sources. The Journal of the Acoustical Society of America, 34(12), 1936–1956. Copyright Acoustical Society of America

Kadlu - at a glance

An open-source Python package for ocean ambient noise modelling

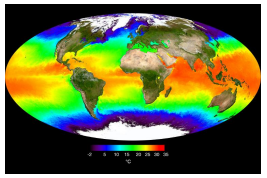
Main features:

- Automated fetching and interpolation of environmental data
- Accurate numerical treatment of sound propagation
- Model output saved to structured database

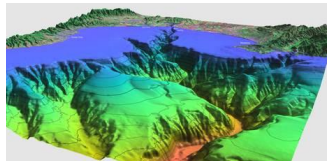
Kadlu - at a glance

Environmental data

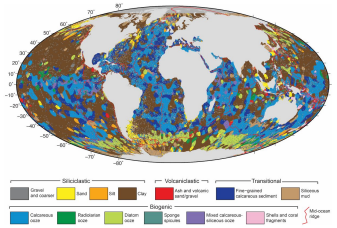
Temperature and salinity



Bathymetry



Seafloor lithology



Waves, wind, currents, tides, ...

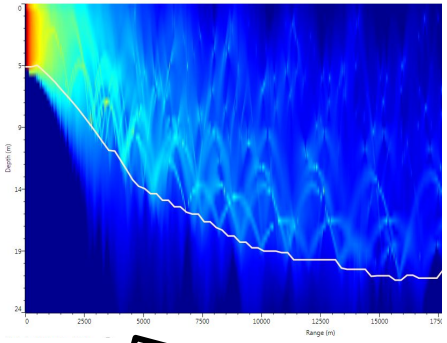
Automated fetching and interpolation

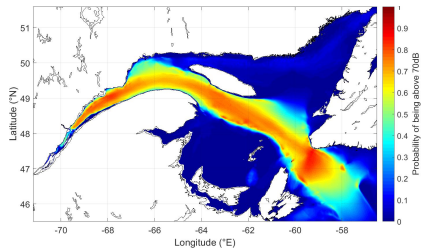
Local database (SQLite)

Sound propagation model

Source levels (SL)

Transmission loss (TL)





SPL = SL - TL

Model output (NetCDF)

Sound propagation model

- Nx2D Thomson-Chapman Parabolic Equation
- Valid for acoustic environments that exhibit weak range dependence
- Split-step Fourier algorithm on a regular grid
- Implemented in Python

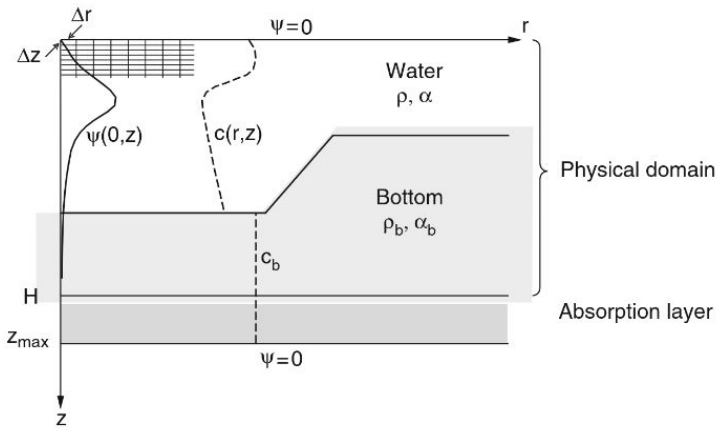


Figure 1: Shematic of PE solution domain (adapted from Jensen).

Model type	Applications							
	Shallow water				Deep water			
	Low frequency		High frequency		Low frequency		High frequency	
	RI	RD	RI	RD	RI	RD	RI	RD
Ray theory	○	○	◑	●	◑	◑	●	●
Normal mode	●	◑	●	◑	●	◑	◑	○
Multipath expansion	○	○	◑	◑	◑	◑	●	◑
Fast field	●	◑	●	◑	●	◑	◑	◑
Parabolic equation	◑	●	○	○	◑	●	◑	◑

Low frequency (<500 Hz)
High frequency (>500 Hz)

RI: range-independent environment
RD: range-dependent environment

● Modeling approach is both applicable (physically) and practical (computationally)

◑ Limitations in accuracy or in speed of execution

○ Neither applicable or practical

Data sources

Source	Variable(s)	Notes
ERA5 – Copernicus Climate Datastore	• Wind speed and direction • Wave height, direction, period • Precipitation type and flux • Energy fluxes and stress	0.5° resolution Global coverage GRIB data format
HYCOM	• Salinity • Temperature • Ocean currents	0.08° resolution Global coverage NetCDF data format
WWIII – NOAA/NCEP WaveWatch Gen 3	• Wind speed and direction • Wave height, direction, period	0.5° x 0.5° global resolution Global coverage GRIB data format
GEBCO	• Bathymetry	15 arc-second resolution Global coverage NetCDF data format

Software package

copyleft license

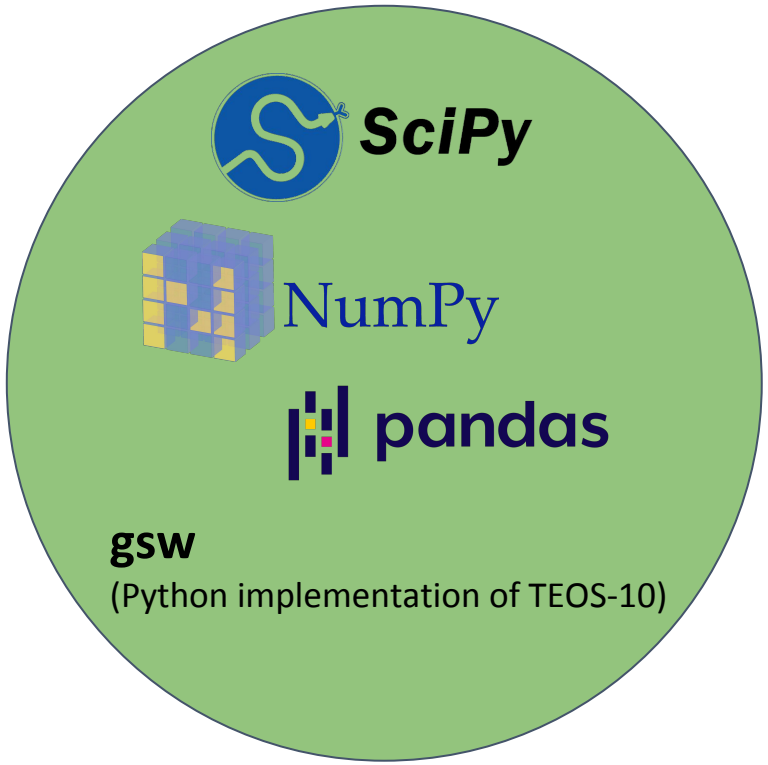
- Written in Python
- GNU GPLv3 license - freely available to use and modify
- Hosted on GitLab: https://gitlab.meridian.cs.dal.ca/public_projects/kadlu
- Fully documented code, including examples: https://docs.meridian.cs.dal.ca/kadlu
- Step-by-step tutorials
- Available on the Python Package Index (PyPi) - the official third-party software repository for Python

Etymology

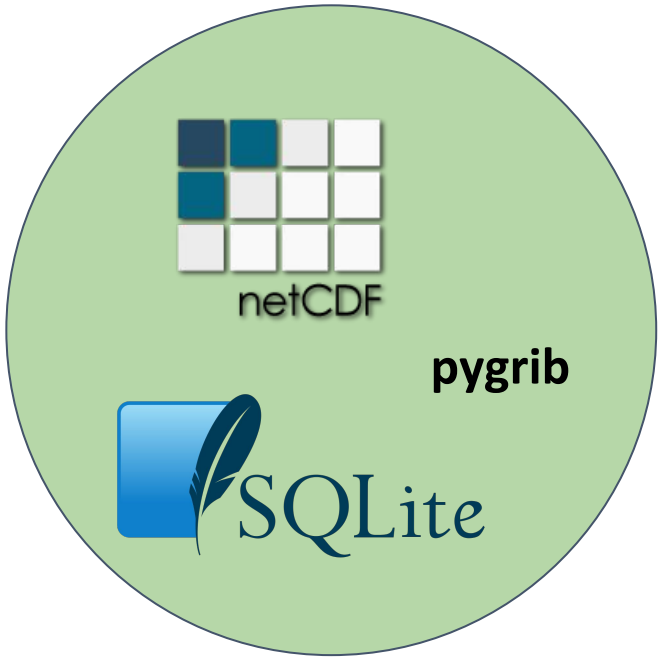
In Inuit mythology, **Kadlu** refers to one of the trinity of sisters, the three goddesses creating thundery weather. She creates thunder by jumping on hollow ice.

Main dependencies

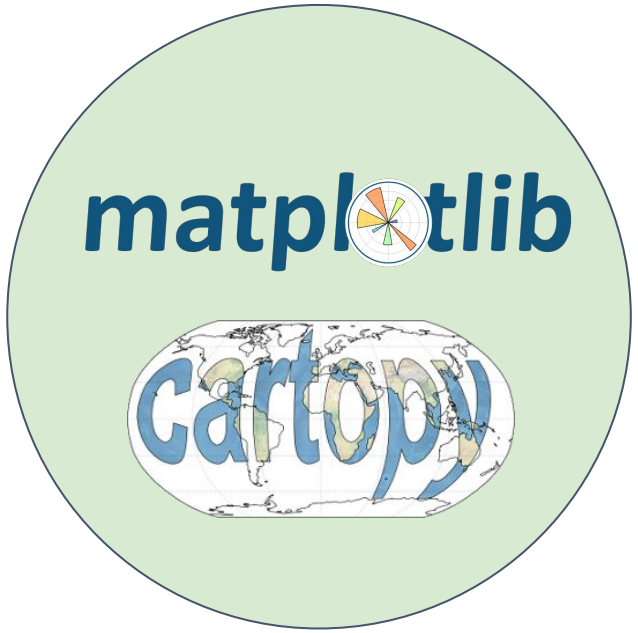
Numerical routines, data interpolation



Loading/storing data



Data visualization



Documentation - https://docs.meridian.cs.dal.ca/kadlu/

kadlu

Ocean ambient noise modelling

2.3

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Kadlu

Introduction

Kadlu is a software package for modeling underwater noise, first released in March 2020. It was developed for the purpose of modelling noise due to waves and rain in shallow coastal waters, but contains tools useful for many other ocean acoustics modeling tasks.

Kadlu is written in Python and utilizes a number of powerful software packages including NumPy, HDF5, NetCDF-4, SQLite, and GDAL. 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/kadlu . Kadlu was developed by the MERIDIAN Data Analytics Team at the Institute for Big Data Analytics at Dalhousie University with the support and assistance of David Barclay and Calder Robinson, both from the Department of Oceanography at Dalhousie University.

Kadlu provides functionalities that automate the process of fetching and interpolating environmental data necessary to model ocean ambient noise levels (bathymetry, water temperature and salinity, wave height, wind speed, etc.). It also includes various routines that allow accurate estimates of noise source levels and transmission losses in realistic ocean environments. You can find more information about the technical aspects of how sound propagation is modelled in Kadlu in this note.

The intended users of Kadlu are researchers and students in underwater acoustics working with ambient noise modeling. While Kadlu 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 physical principles of underwater sound propagation would also be an advantage.

To get started with Kadlu, follow the Install instructions and then proceed to the Tutorials section.

In Inuit mythology, Kadlu is the name of a goddess that creates thundery weather, for example, by jumping on hollow ice. Thus, the name Kadlu was chosen to highlight the software package's main intended application, modeling of noise due to environmental forcings.

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Summary

An open-source Python package for ocean ambient noise modelling

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Check it out at https://docs.meridian.cs.dal.ca/kadlu/