Norwegian Meteorological Institute

Advanced Metocean Analysis based on Open Resources

Konstantinos Christakos, MET Norway & NTNU
Contributions by: Jan-Victor Björkqvist, Clio Michel, Birgitte Furevik, Marte S. Vindedal (UiB)

Marin Byggteknikkdagen 10. april 2025 i Trondheim

Why is metocean important?

Metocean studies are crucial for offshore and coastal engineering due to several reasons:

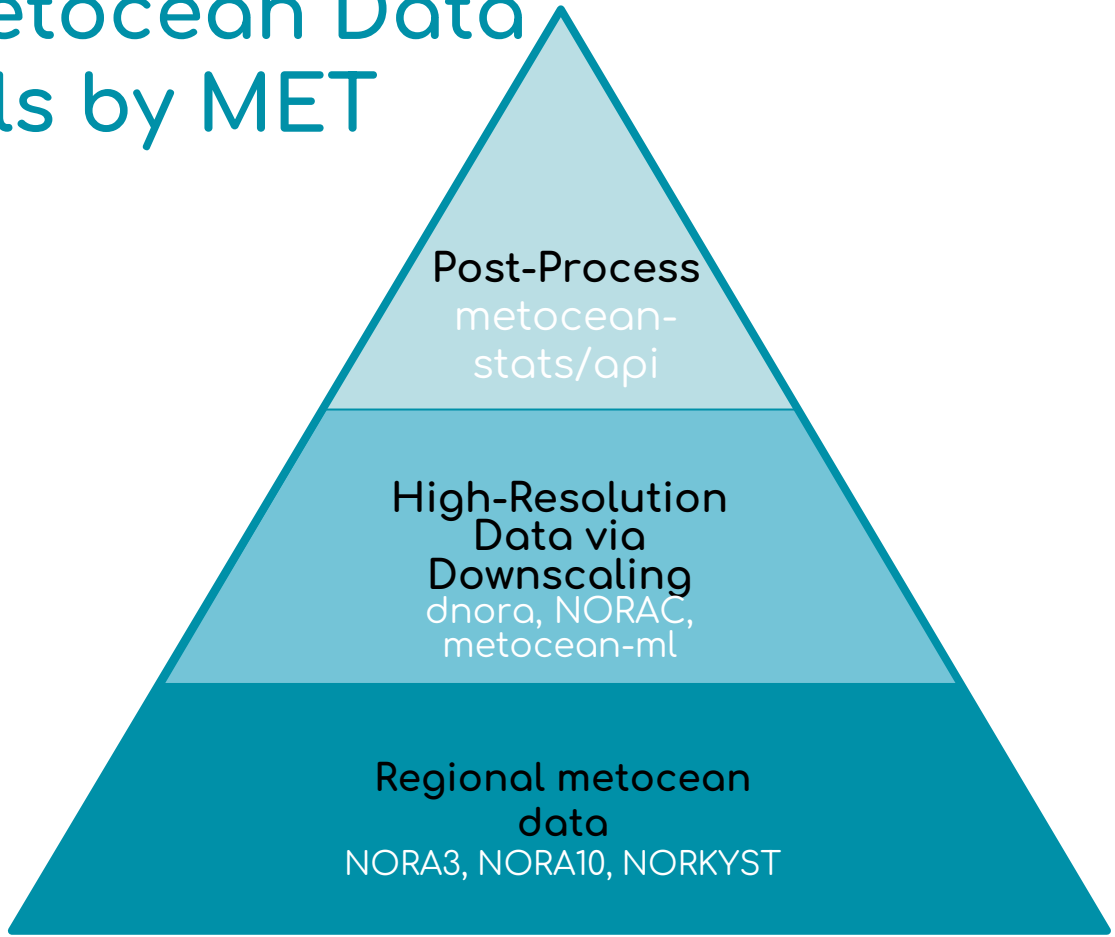
Design: Metocean studies provide critical information for the design and installation of offshore and coastal structures.

Efficient Operations: Accurate metocean data can improve operational efficiency by enabling better planning.

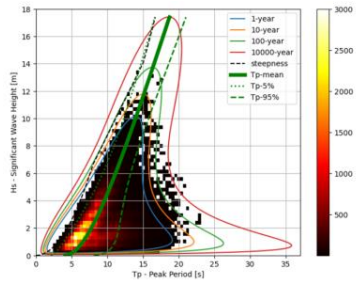
Safety: Understanding the metocean conditions of a particular area can help ensure the safety of marine operations.

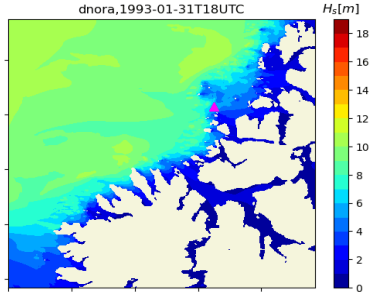
Metocean data/analysis is used as input for engineering models.

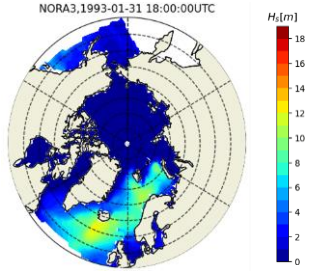
Open Metocean Data and Tools by MET



metocean-stats







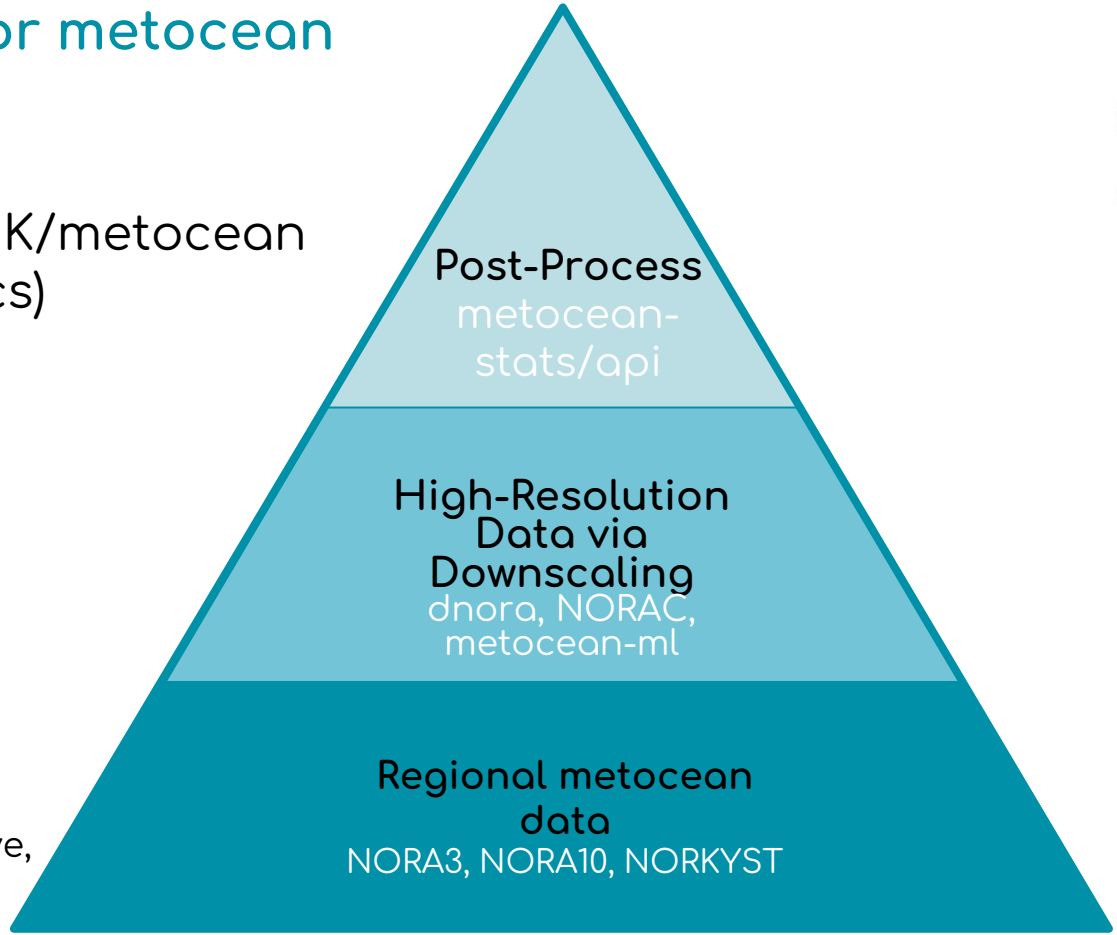
Norwegian Meteorological Institute

Typical $$$ for metocean products

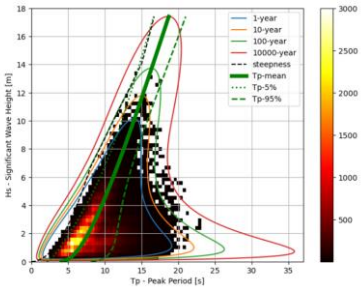
up to ~0.6 MNOK/metocean report (statistics)

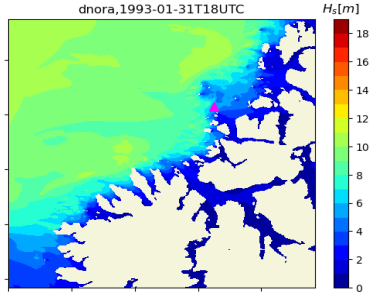
~1+ MNOK/ Downscaling

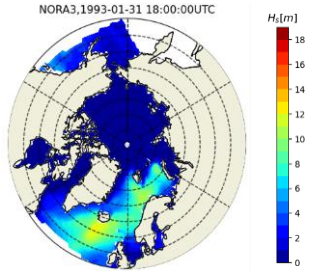
~15 MNOK for NORA3 (wind, wave, storm surge)



metocean-stats





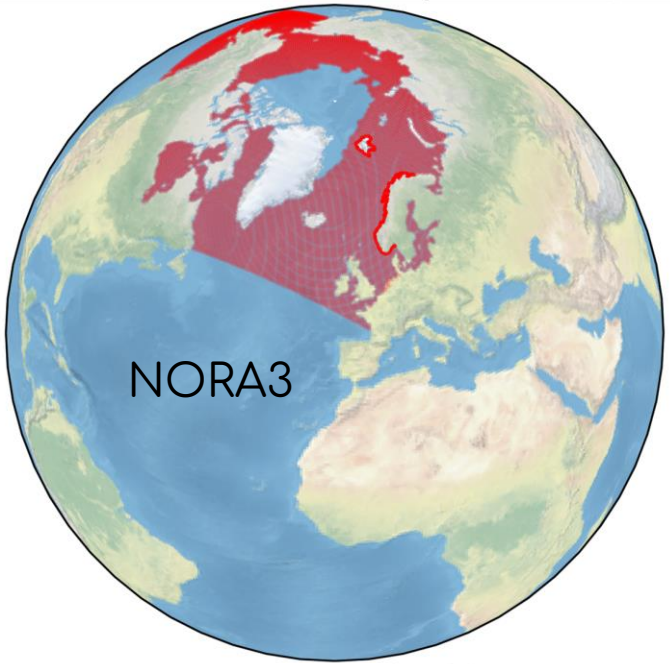


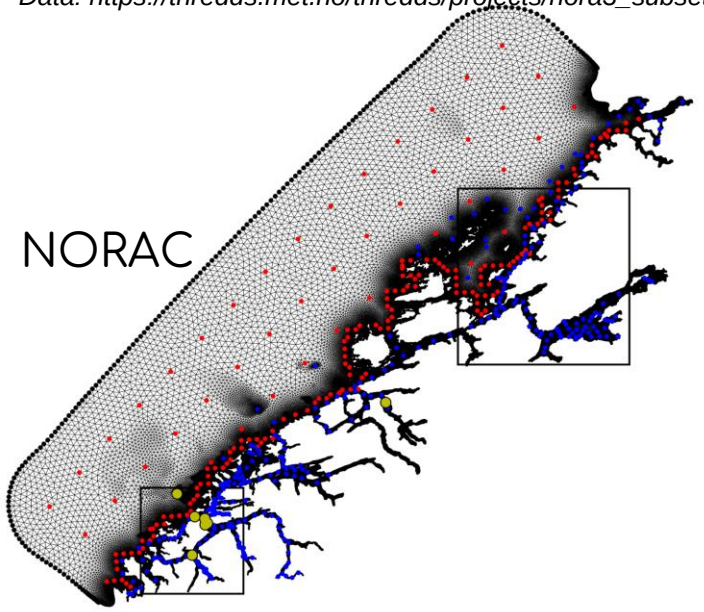
Norwegian Meteorological Institute

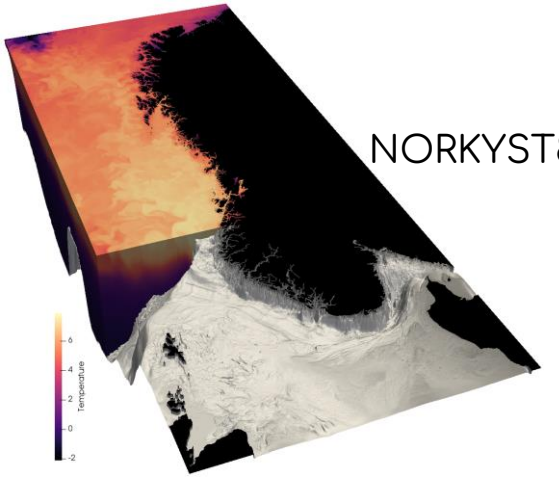
Open Metocean Data (hindcast) at MET

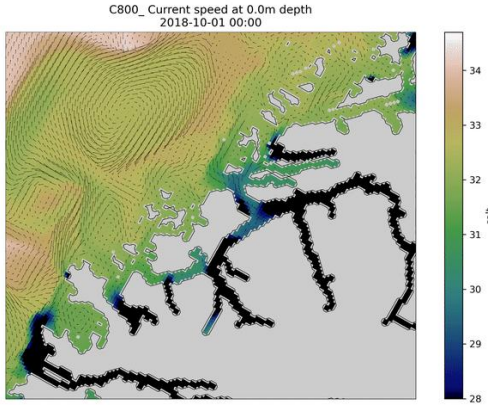
1. NORA3 (wind, waves, storm surge/Nordic)
2. NORAC (coastal waves)
3. NORKYST800 (ocean currents)

Data: https://thredds.met.no/thredds/projects/nora3_subsets.html



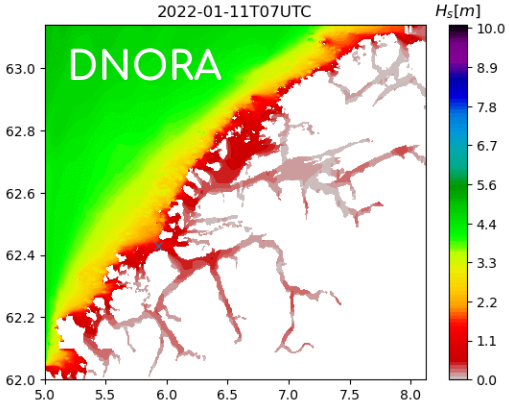


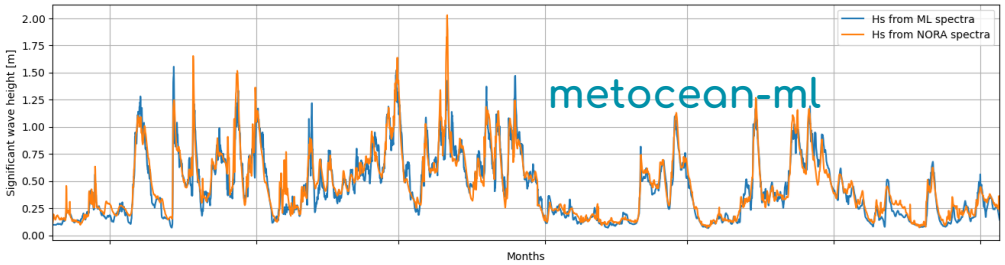


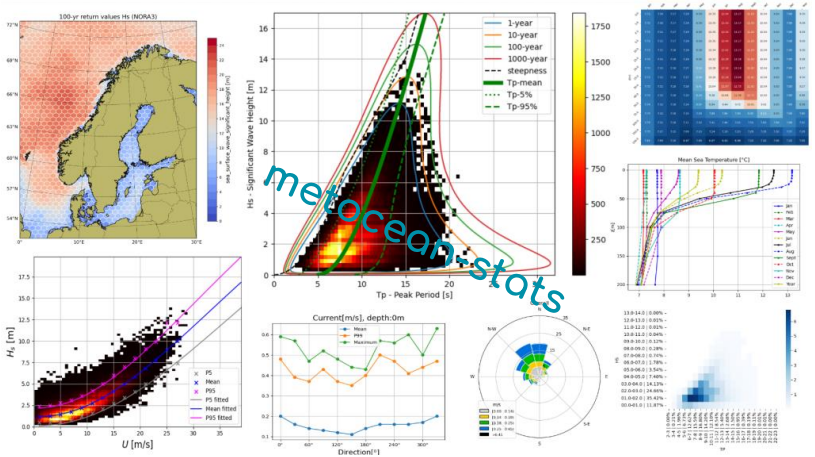


Open Metocean Software Development at MET

1. DNORA to dynamical downscale ocean wave data to high-resolution.
2. **metocean-api** to extract metocean data as csv-files (import in e.g. excel) from hindcast datasets
3. **metocean-stats** to create metocean statistics for a specific location.
4. **metocean-ml** for downscaling of metocean data using machine learning (under development)







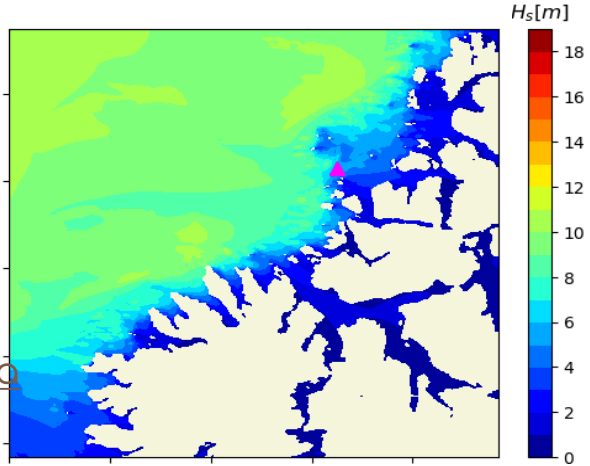
Norwegian Meteorological Institute

What is DNORA?

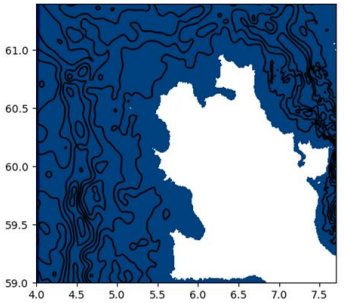
DNORA is an open-source Python package for dynamical downscaling of wave hindcast and forecast using wave models

dynamical dnora downscaling

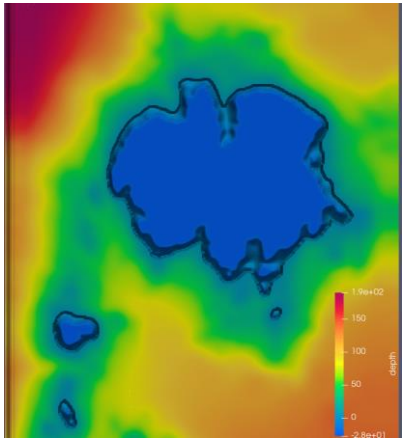
SWAN



SWASH



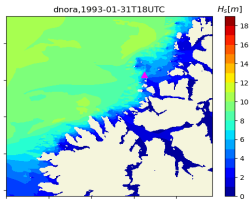
REEF3D::FNPF



DNORA is available at:
https://github.com/MET-OM/dnora

Supported models in DNORA

Spectral models



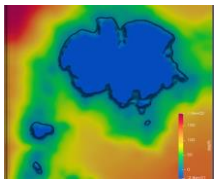
SWAN

- Grid generation
- Wind forcing
- Boundary
- Input files
- Run model

WAVEWATCH III

- Grid generation
- Wind forcing
- Boundary

Phase resolving models



SWASH

- Grid generation
- Boundary
- Input files
- Run model

REEF 3D

- Grid generation
- Boundary
- Input files
- Run model

HOS-ocean

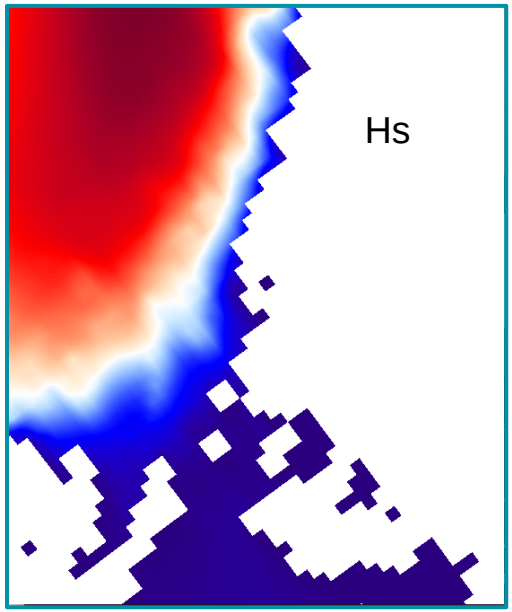
- Grid generation
- Boundary
- Input files
- Run model

Why DNORA?

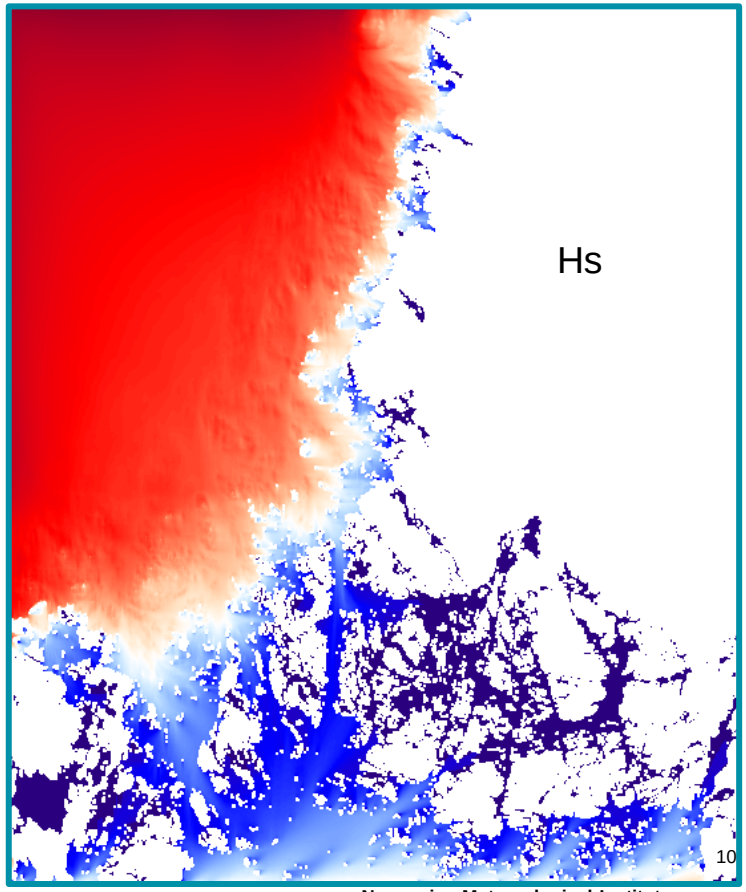
- The spatial resolution (3km) of NORA3 is too coarse for the complex Norwegian coastline. There is a need for downscaling!
- DNORA automates the pre-processing saving time and resources.
- It uses advanced modelling techniques for realistic ocean simulations
- A tool that can be used for research/educational/practical purposes (coastal engineering, metocean design basis, climate studies, input for structural studies etc.)

From NORA3 to DNORA

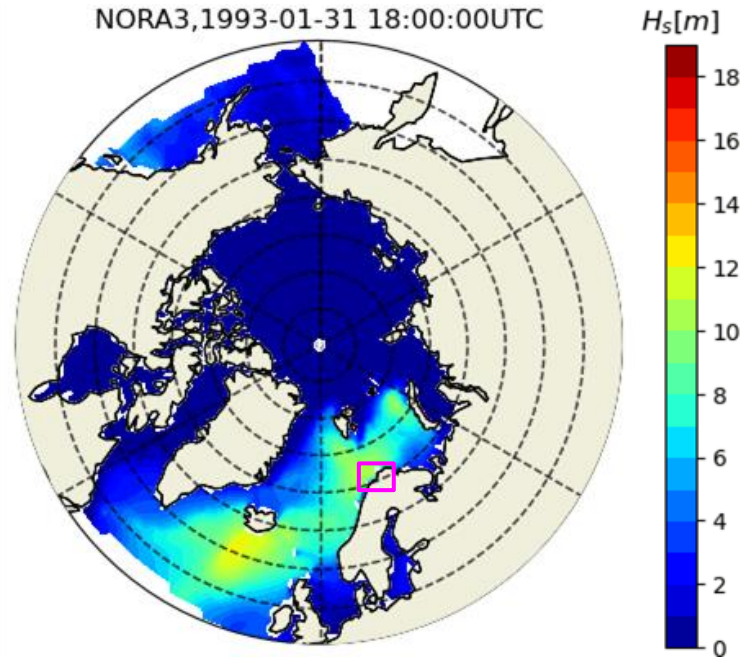
NORA3



Dynamical DNORA Downscaling

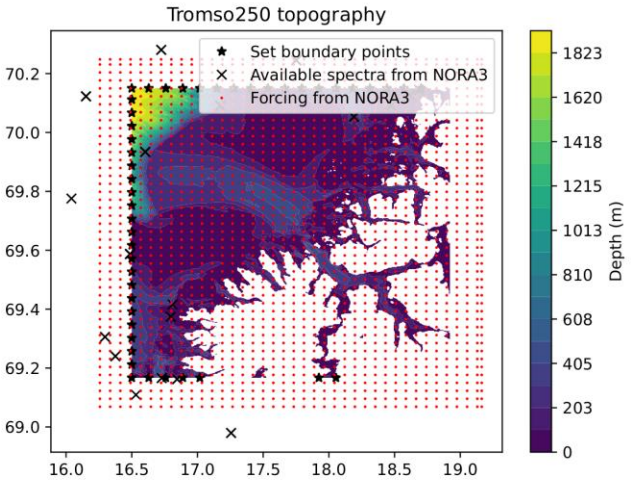


Example: DNORA/SWAN using NORA3



Example: DNORA(v1)/SWAN using NORA3

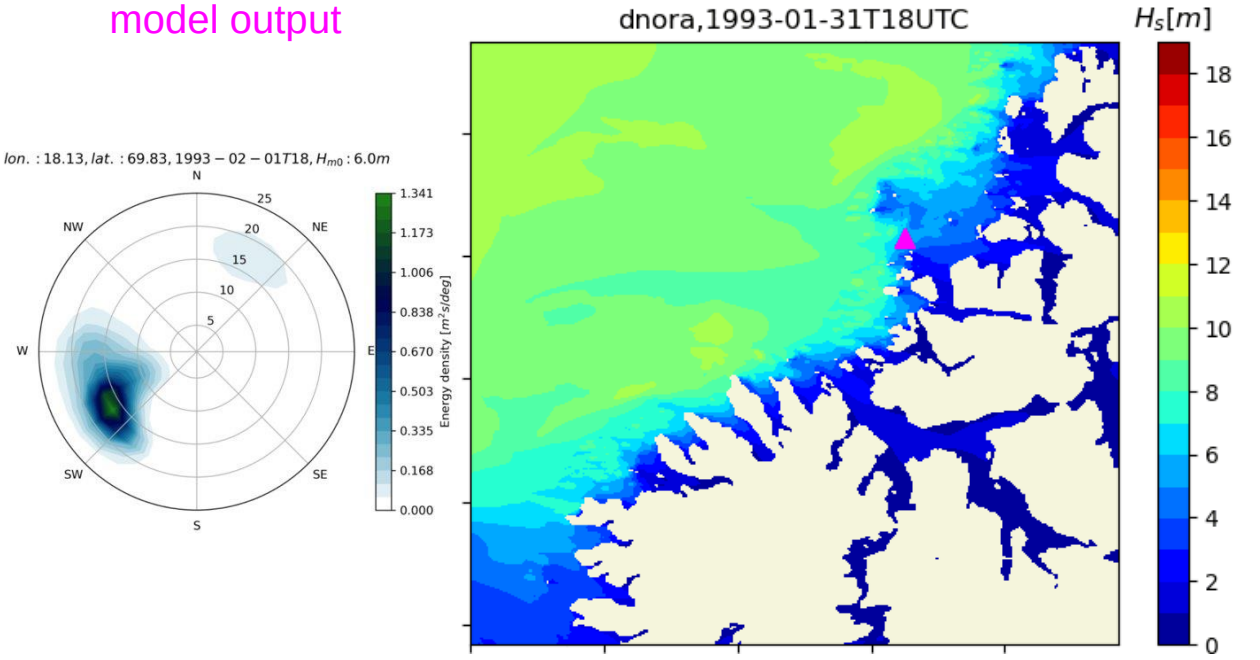
```
from dnora import grd, mdl

# ============================================================================
# DEFINE THE MODEL GRID, INCLUDING RESOLUTION, BOUNDARY POINTS AND DEPTH DATA
# ============================================================================
grid = grd.Grid(lon=(16.500, 18.9212), lat=(69.167, 70.150), name='Tromso250')
grid.set_spacing(dm=250)
grid.set_boundary(grd.boundary.EdgesAsBoundary(edges=['N','W','S'], step=20))

grid.import_topo(grd.read.EMODNET2020(tile='C*',folder='local_folder'))
grid.mesh_grid()

# ============================================================================
# CREATE A MODEL RUN FOR THE GRID AREA AND A SPECIFIED TIME PERIOD
# ============================================================================
model = mdl.SWAN_NORA3(grid, start_time='1993-01-31T12:00',
                             end_time='1993-02-04T12:00')

model.import_boundary()
model.import_forcing()

model.plot_grid(save_fig=True, show_fig=False)

# ============================================================================
# EXPORT THE NECESSART FORCING DATA FOR THE MODEL
# ============================================================================
model.export_grid()
model.export_boundary()
model.export_forcing()

# ============================================================================
# WRITE THE MODEL INPUT FILE AND RUN THE SWAN WAVE MODEL
# ============================================================================
model.write_input_file()
model.run_model()
```

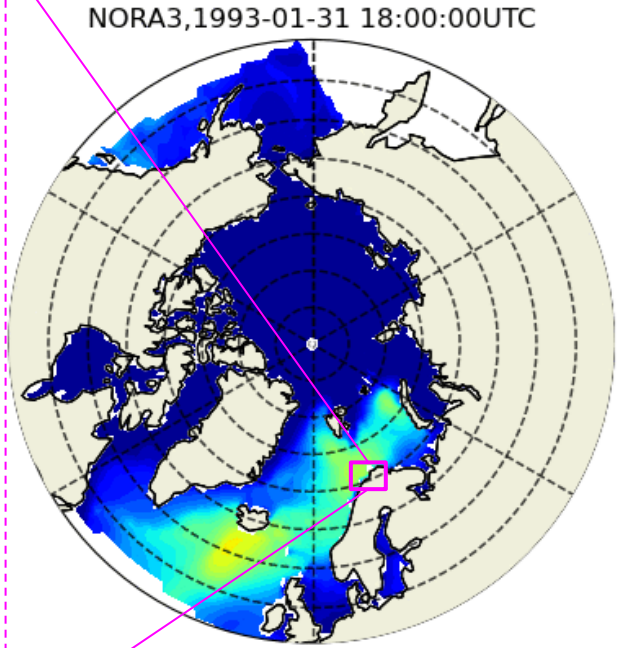


- Tromso250_SWAN.bot
- specNORA3Tromso25019930131_19930204.asc
- windNORA3Tromso25019930131_19930204.asc

Example: DNORA/SWAN using NORA3

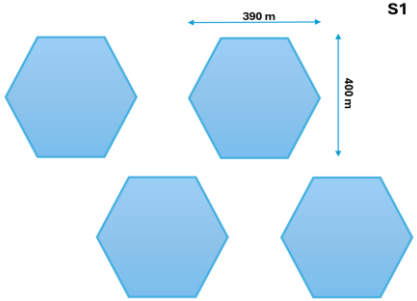
model output

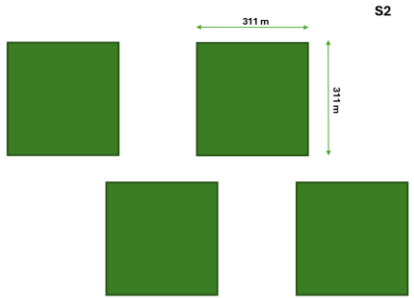


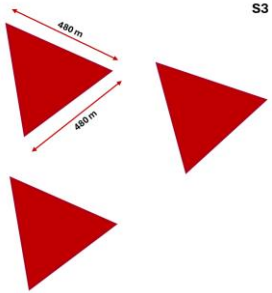


Implementation of marine structures in DNORA(v2)

Example of marine structures: floating solar panels








```python
exe = dn.executer.SWAN(model)
structures = []
# Line
structures.append(
    {"lon": (5.4, 5.5), "lat": (59.1, 59.13), "trans": 0.3, "name": "breakwater"}
)
# closed square
structures.append(
    {
        "lon": (5.4, 5.5, 5.5, 5.4),
        "lat": (59.15, 59.15, 59.14, 59.14),
        "trans": 0.4,
        "closed": True,
        "name": "floating square",
    }
)
# Two sides of a triangle. Make it a triangle by 'closed': True. Uses same transparency as the previous object
structures.append(
    {
        "lon": (5.36, 5.38, 5.41),
        "lat": (59.01, 59.05, 59.01),
        "name": "spearhead",
        "refl": 0.9,
    }
)

exe.write_input_file(structures=structures)
```

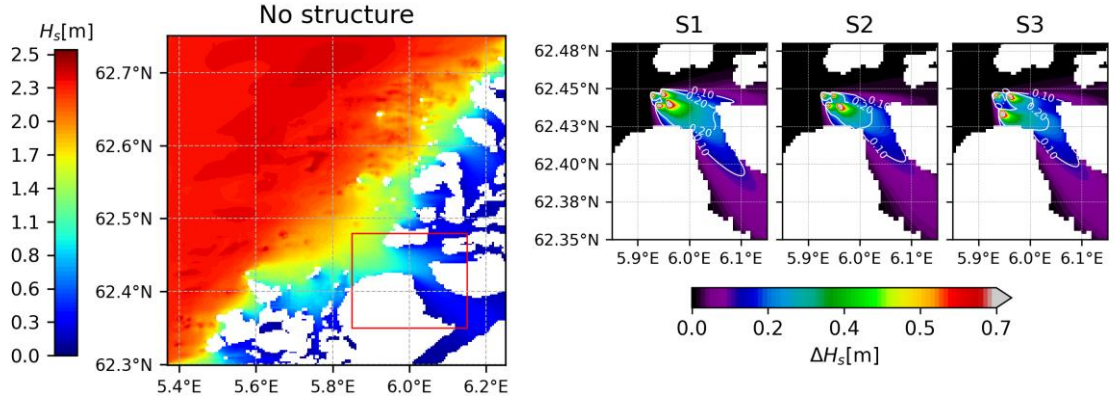
DNORA Implementation by
Jan-Victor Björkqvist (MET Norway)

Simulations by Master (Energy) student
Marte S. Vindedal (UiB)

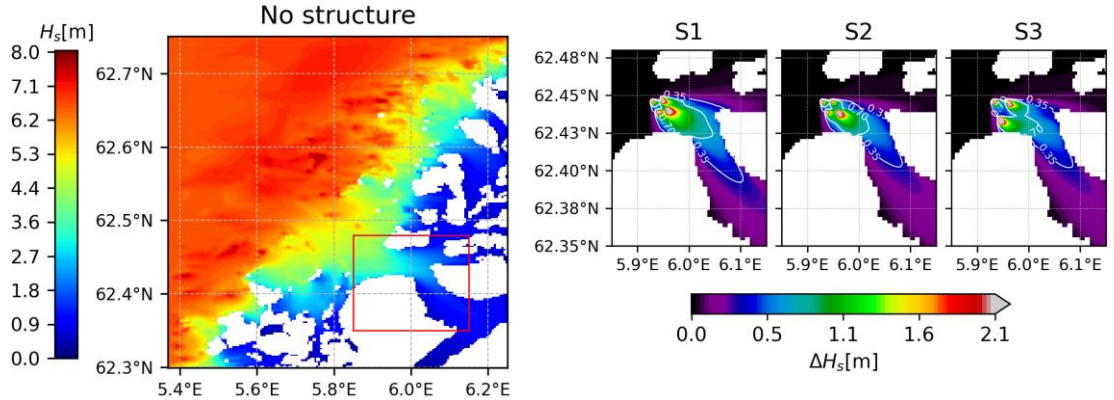
Norwegian Meteorological Institute

Implementation of marine structures in DNORA(v2)

Simulations by Master (Energy) student Marte S. Vindedal (UiB)



Mean



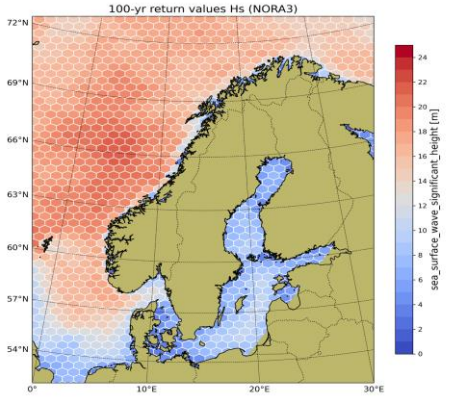
99th percentile

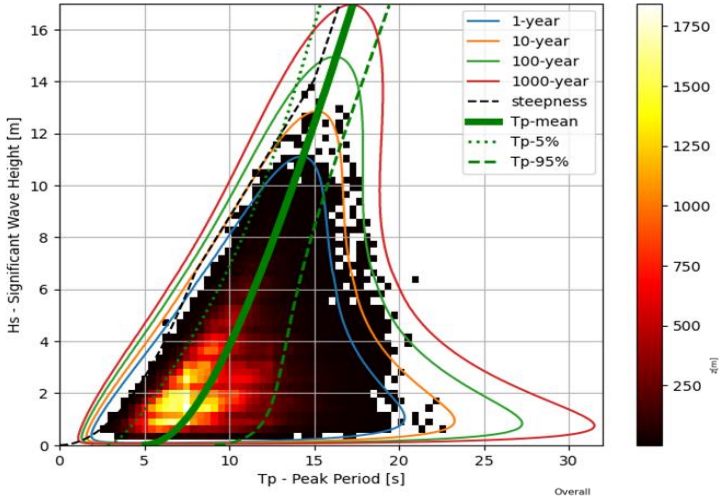
Norwegian Meteorological Institute

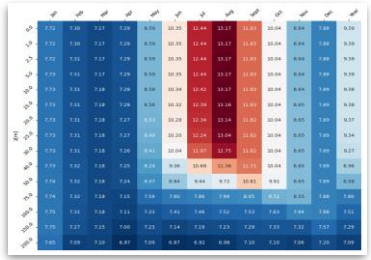
What is metocean-stats?

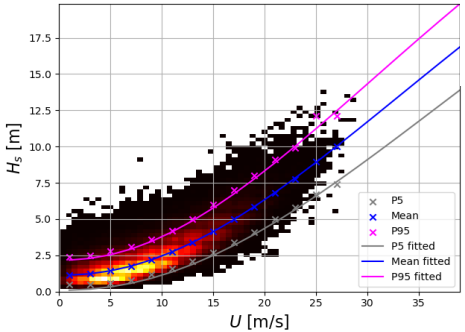
metocean-stats is a open-source Python tool for comprehensive statistics and visualization of metocean data.

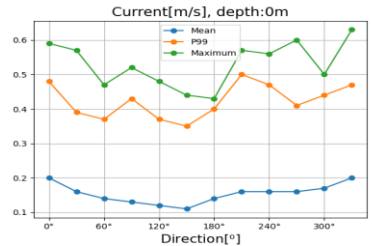
- The input data is provided as a Pandas **DataFrame** (time series of metocean variables) from a **single** position.
- The tool also includes spatial statistics (maps).
- Source code: https://github.com/MET-OM/metocean-stats

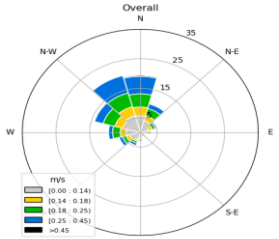


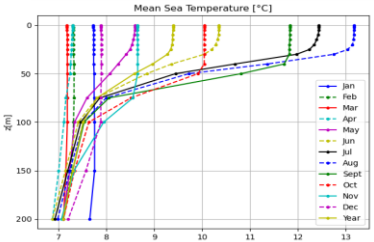


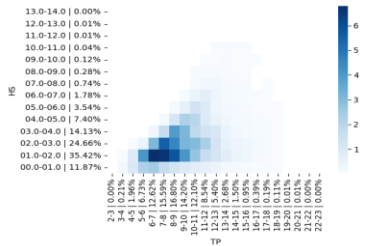












Easy to install metocean-stats via conda / pip

pypi.org/project/metocean-stats/

Search projects

metocean-stats 1.0.4

```
pip install metocean-stats
```

metocean-stats - Tool for generation of metocean statistics

Package for metocean statistics of hindcast/reanalysis data

copied from cf-staging / metocean-stats

Conda | Files | Labels | Badges

License: LGPL-2.0-only
Home: https://github.com/MET-OM/metocean-stats
Development: https://github.com/MET-OM/metocean-stats
Documentation: https://metocean-stats.readthedocs.io/
4539 total downloads
Last upload: 1 month and 19 days ago

Installers

noarch v1.0.4

conda install

To install this package run one of the following:

```
conda install conda-forge::metocean-stats
```

Contributors 10

Languages

Python 100.0%

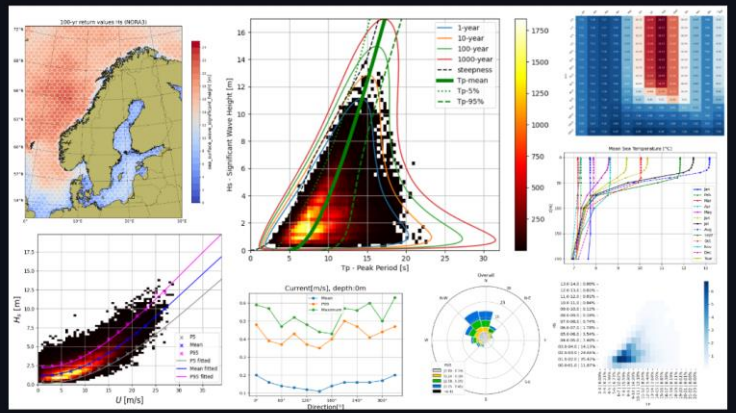
README | LGPL-3.0 license

metocean-stats

Tests passing | docs passing

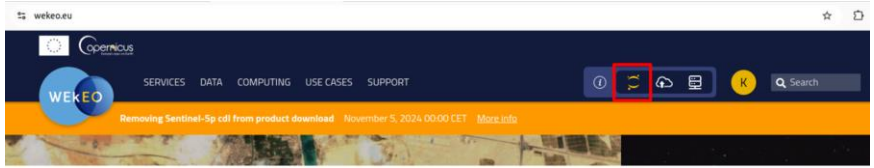
Purpose

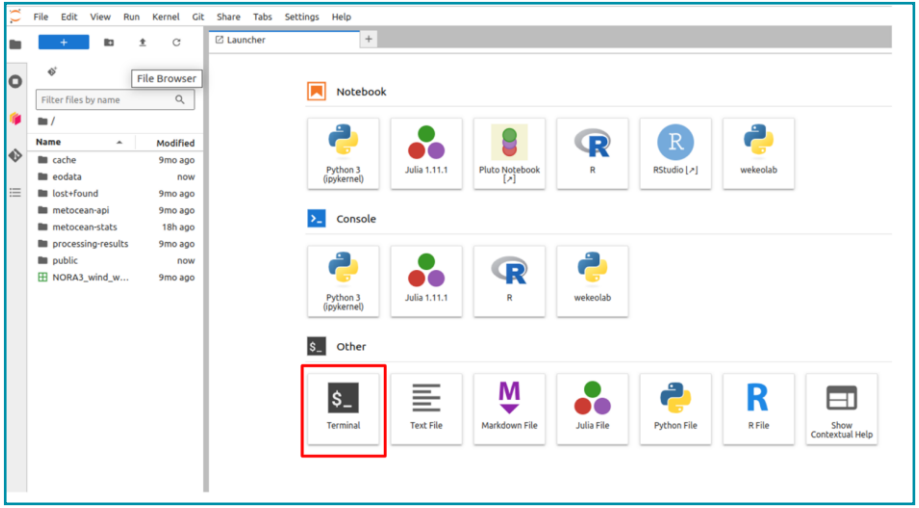
Metocean-stats is a tool for comprehensive statistics and visualization of metocean data (wind, waves, ocean currents, tide levels, air and water temperature, sea ice, and more). The tool is also compatible with WEkEO Jupyter Lab, allowing seamless integration and use. For instructions on how to install metocean-stats in WEkEO, please refer here.



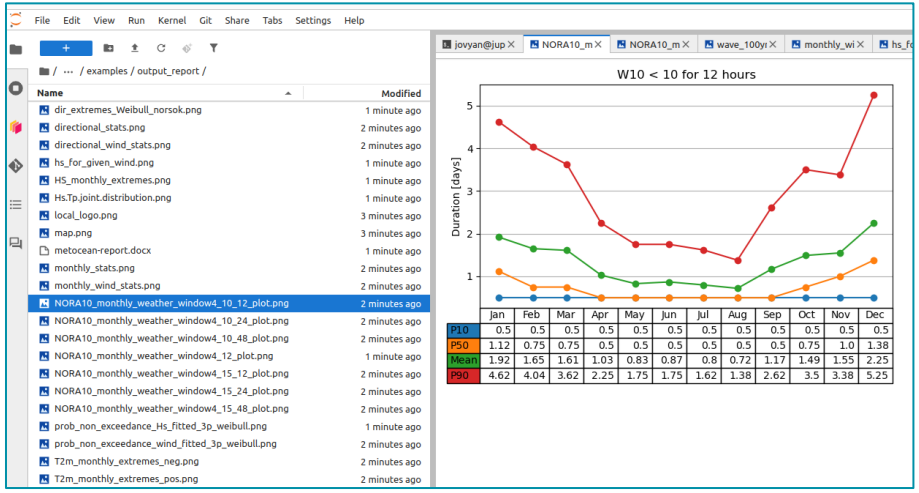
⚠️ Please note that while metocean-stats is designed to provide accurate statistics and visualizations of metocean data, the user is ultimately responsible for correctly using the tool and interpreting the results. The tool is not liable for any errors or actions taken based on the information provided by the tool. Users should cross-verify the results and use them with discretion.

Cloud Compatibility





metocean-stats is compatible with cloud computing services such as **WEkEO JupyterHub** (free Copernicus service), enabling seamless integration and usage within the environment.



Norwegian Meteorological Institute

Students: metocean-stats/automated report

SFI BLUES

Konstantinos Christakos • You
Researcher | Lecturer | Creating Metocean Tools for Maritime, Ene…
3w • Edited •

🌊 Developments in open-source programs often come from students through master's projects and internships, and we've seen this firsthand!

This time, three talented students from the Integrated Master's program in Energy at **University of Bergen (UiB)** contributed to our open-source metocean statistical tools, metocean-stats and metocean-ml, during their internships. ⏱️

Sofie Engler-Christensen explored various machine learning techniques 🤖to analyze metocean and wind power data, while **Anna Tanderø SVhaug** and **Anne-Ida Nordengen** developed functions to automate metocean report generation 🖥️📊

Thank you for your dedication and hard work! 🌟

#metocean #energy #opensource #python #internship #machinelearning #innovation

Birgitte Rugaard Furevik and 52 others 1 comment · 1 repost

Like Comment Repost Send

4,198 impressions View analytics

North Sea Metocean Design Basis

Longitude: 3
Latitude: 60

Date: 03.12.2024

Created by: metocean-stats

Title: North Sea Metocean Design Basis
Date: 03.12.2024

Table of Contents

1 av 65

Title: North Sea Metocean Design Basis
Date: 03.12.2024

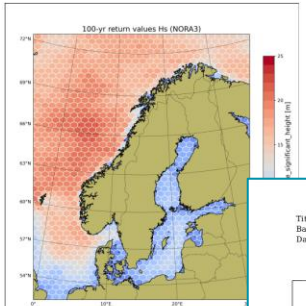


Figure 3.3: 100-year return period for significant wave hei
Nordics based on NORA3 (period: 1991-2020) using Gumbel
(Annual maxima).

6 av 65

Title: North Sea Metocean Design Basis
Date: 03.12.2024

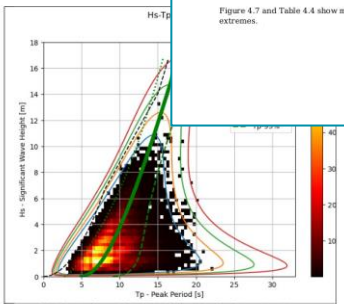


Figure 5.10: Contour lines of Hs - Tp including wave breaking criteria/steepness , with return period 1, 10, 100 and 1000 years for omni-directional waves at the North Sea field. Duration of sea state is 3 hours.

5.1.5 Individual waves and crest heights

Table 5.13 shows the estimated design wave heights. Extreme value estimates for individual wave heights and wave crests are computed using the Forristal distribution. The wave periods, T_Hmax, are computed from T_Hmax = 0.90 • Tp, where Tp is given in Table 5.8.Extreme individual wave heights versus direction sectors are given in Table 5.14. These wave heights are determined from the significant wave heights given in Table 5.9 by assuming that Hmax/Hs for each

Title: North Sea Metocean Design Basis
Date: 03.12.2024

Table 4.3: Weibull parameters and corresponding adjusted directional extreme values for 1-hour mean wind speed 10 m above sea level at the North Sea field. Duration of the event is 1 hour. The direction extremes are adjusted in agreement with NORSOK Standard N-003:2017

Direction sector	Sector prob.	Shape	Scale	Location	Return period: 1 [years]	Return period: 10 [years]	Return period: 100 [years]	Return period: 10000 [years]
	%		m/s	m/s	m/s	m/s	m/s	m/s
0°	13.0	2.6	10.9	-1.0	22.7	25.2	27.4	31.0
30°	5.3	1.9	7.3	0.1	20.6	24.0	27.0	32.3
60°	2.8	1.6	4.6	0.6	14.8	17.8	20.6	25.5
90°	3.0	1.7	5.4	0.2	15.7	18.8	21.6	26.4
120°	5.5	1.9	8.3	-0.2	22.4	26.0	29.3	34.9
150°	14.2	2.6	14.2	-2.2	25.9	29.2	32.2	37.2
180°	15.0	2.6	11.5	-0.7	24.8	27.4	29.8	33.7
210°	9.6	2.5	10.6	-0.9	22.4	25.1	27.3	31.2
240°	8.4	2.6	11.0	-1.3	22.3	24.9	27.2	31.0
270°	7.0	2.3	10.3	-0.8	23.3	26.4	29.1	33.8
300°	6.6	1.9	8.2	0.5	24.0	27.8	31.3	37.2
330°	9.4	2.1	9.2	-0.1	23.9	27.2	30.1	35.2
Omni	100.0	2.2	10.1	-0.5	25.9	29.2	32.2	37.2

Figure 4.7 and Table 4.4 show monthly Weibull parameters and corresponding extremes.

Norwegian Meteorological Institute

Costs - Accessibility - Decision Making

- **Cost Reduction**: metocean-stats can drastically lower the cost of metocean analysis from MNOK to kNOK.
- **Accessibility**: Companies that previously could not afford metocean analysis now have access to this analysis.
- **Enhanced Decision-Making**: By providing affordable metocean analysis, companies can make more informed decisions regarding site selection, design, and operational planning.

NORA3 → metocean-stats → report → Decision Making

Norwegian Meteorological Institute


Norwegian
Meteorological
Institute
Questions?