CTCN Project

Wave Modelling Training

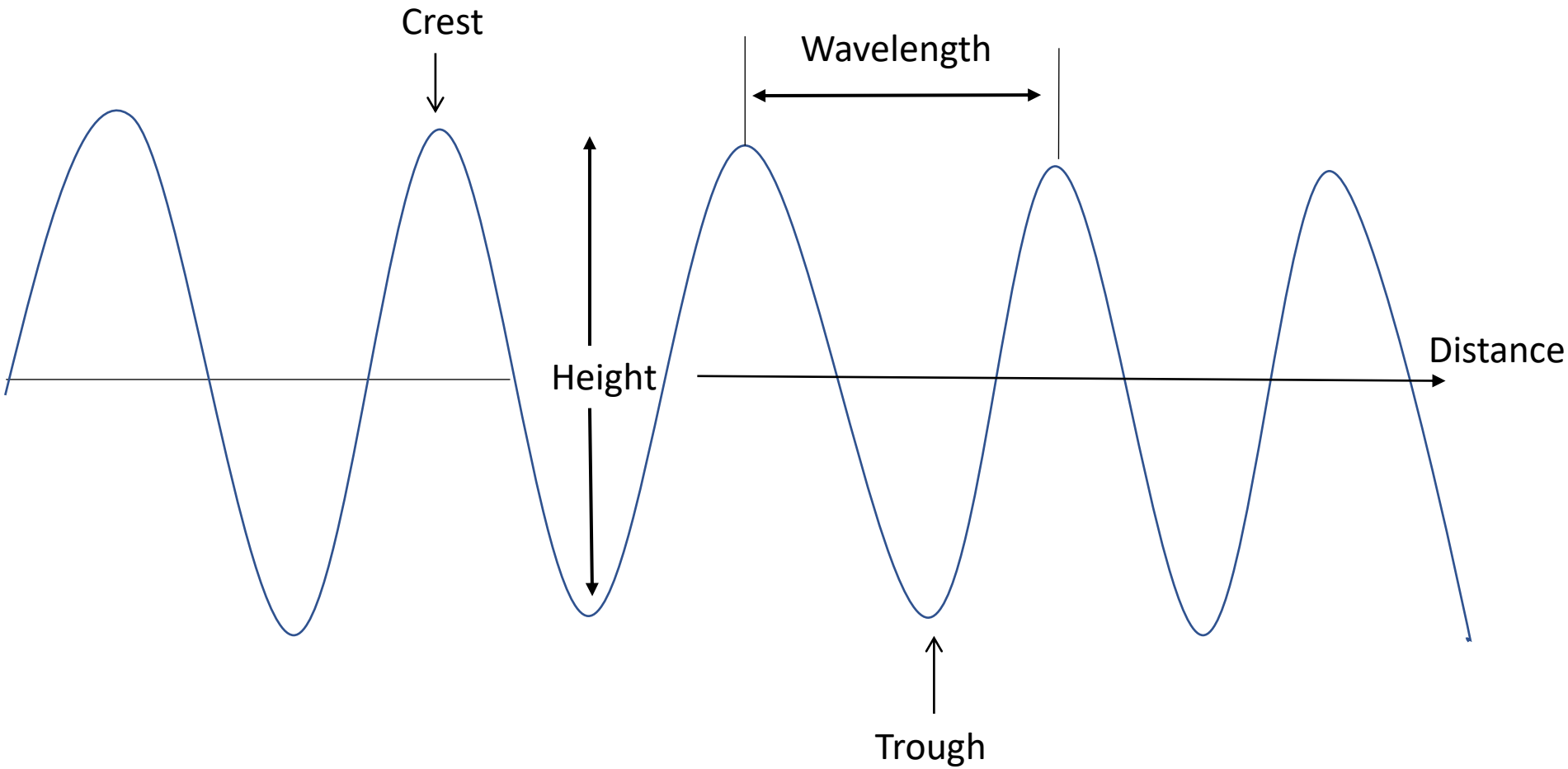
Topics

- Wave models developed

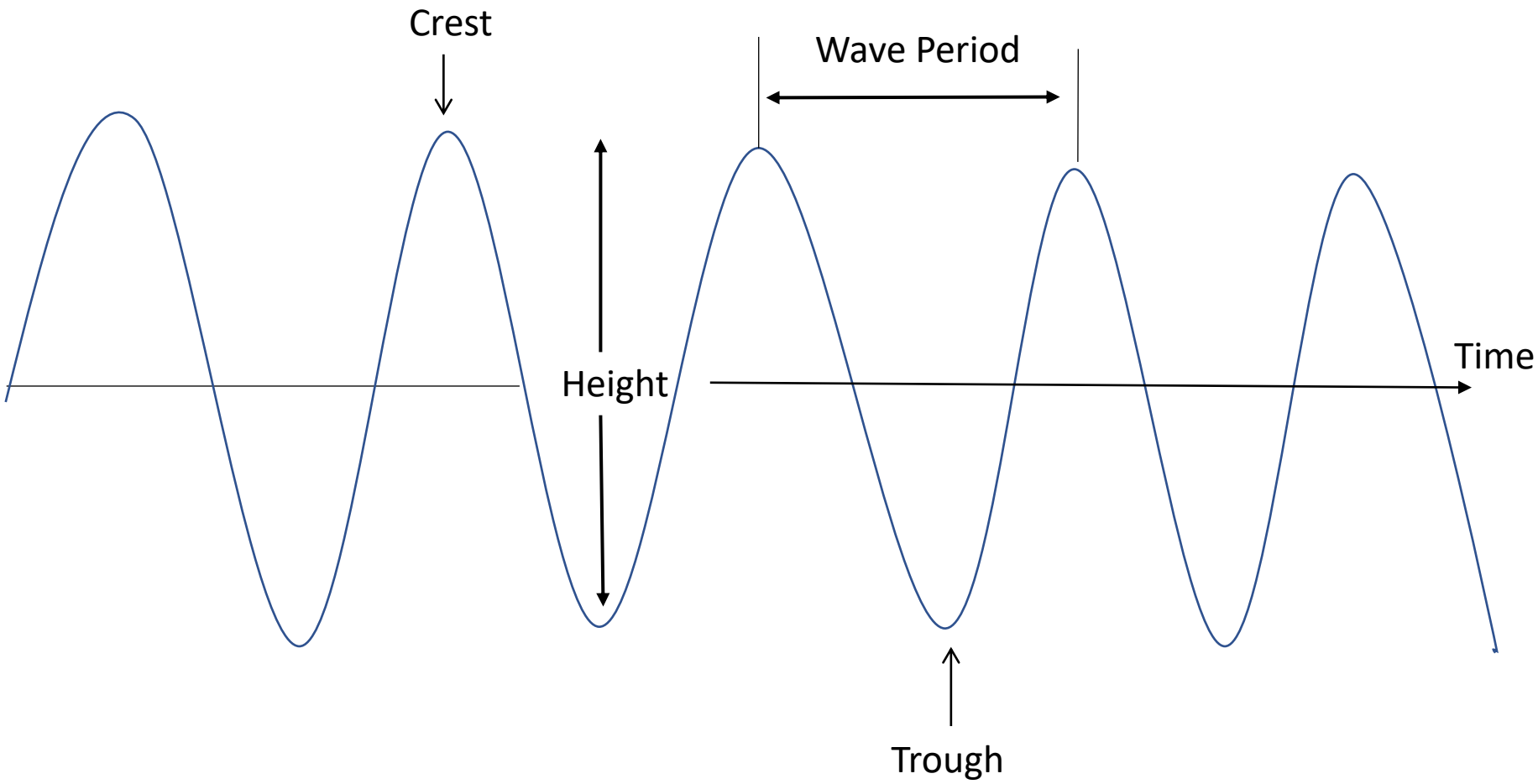
- User Interface Developed

- Discussion: How could this capacity be used in-country?

BASIC OF WAVE



Basic of Wave



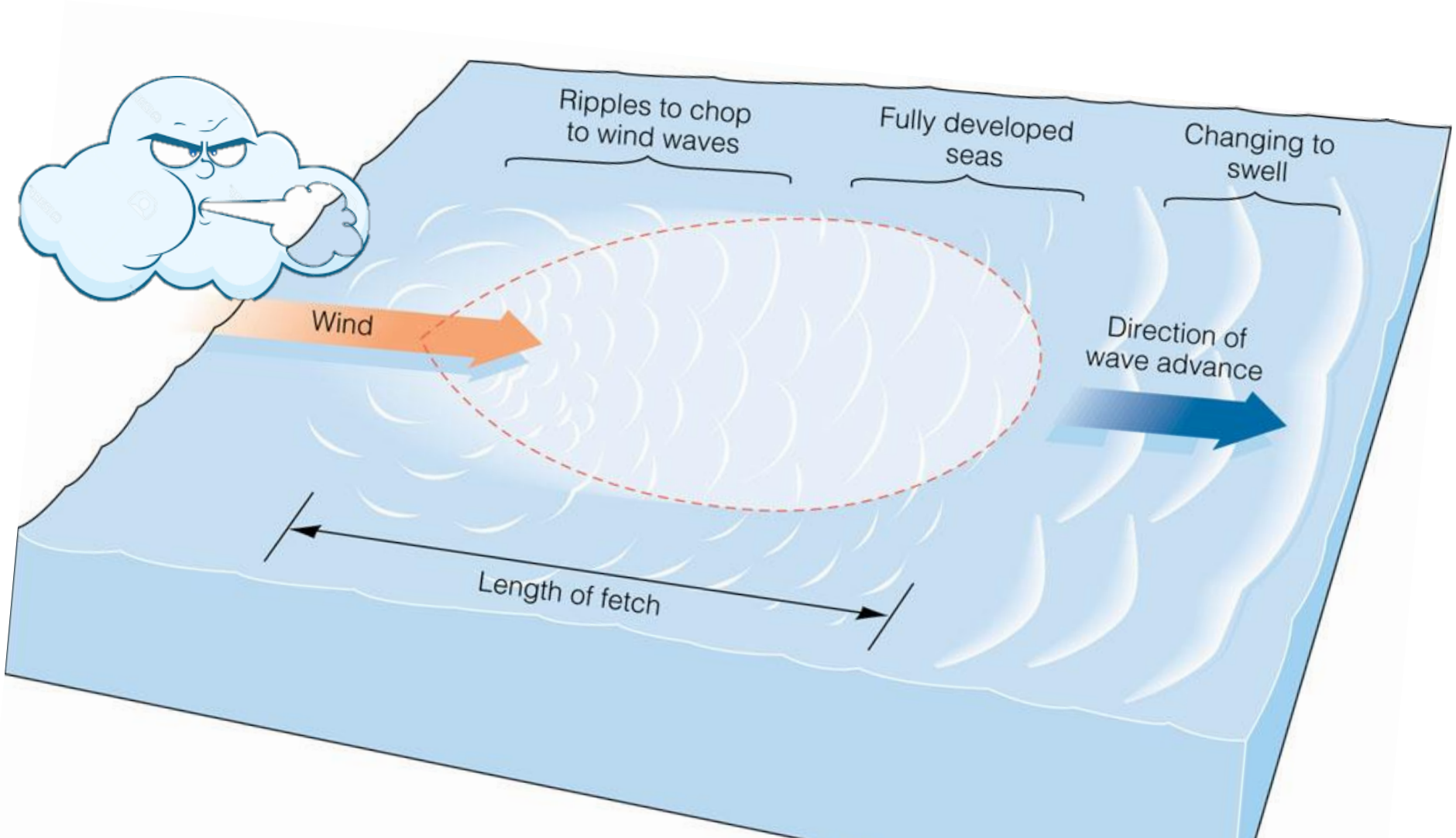
Wind Wave Generation

Influenced by:

Wind Strength

Wind Duration

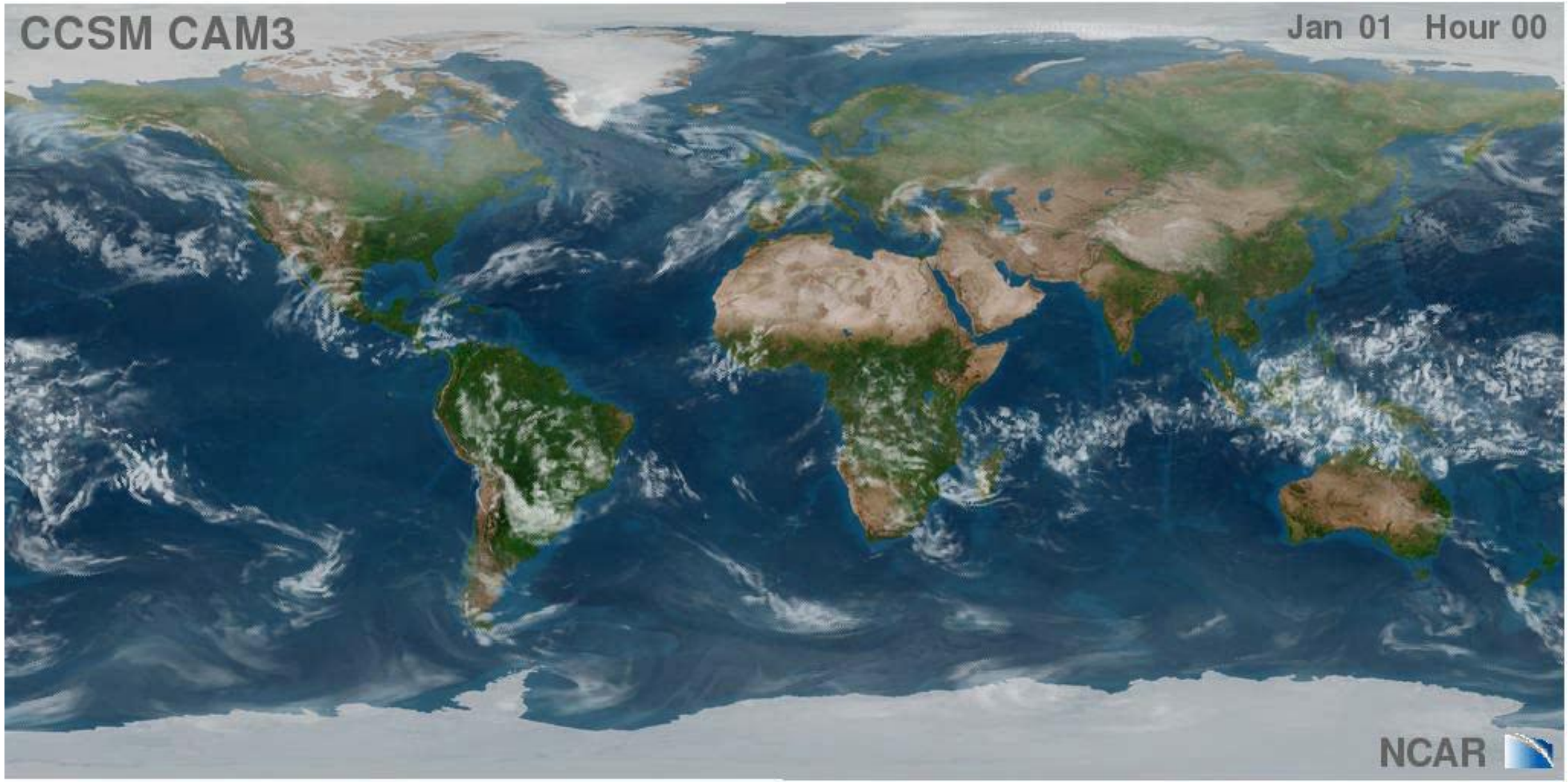
Fetch



Fully Developed Sea

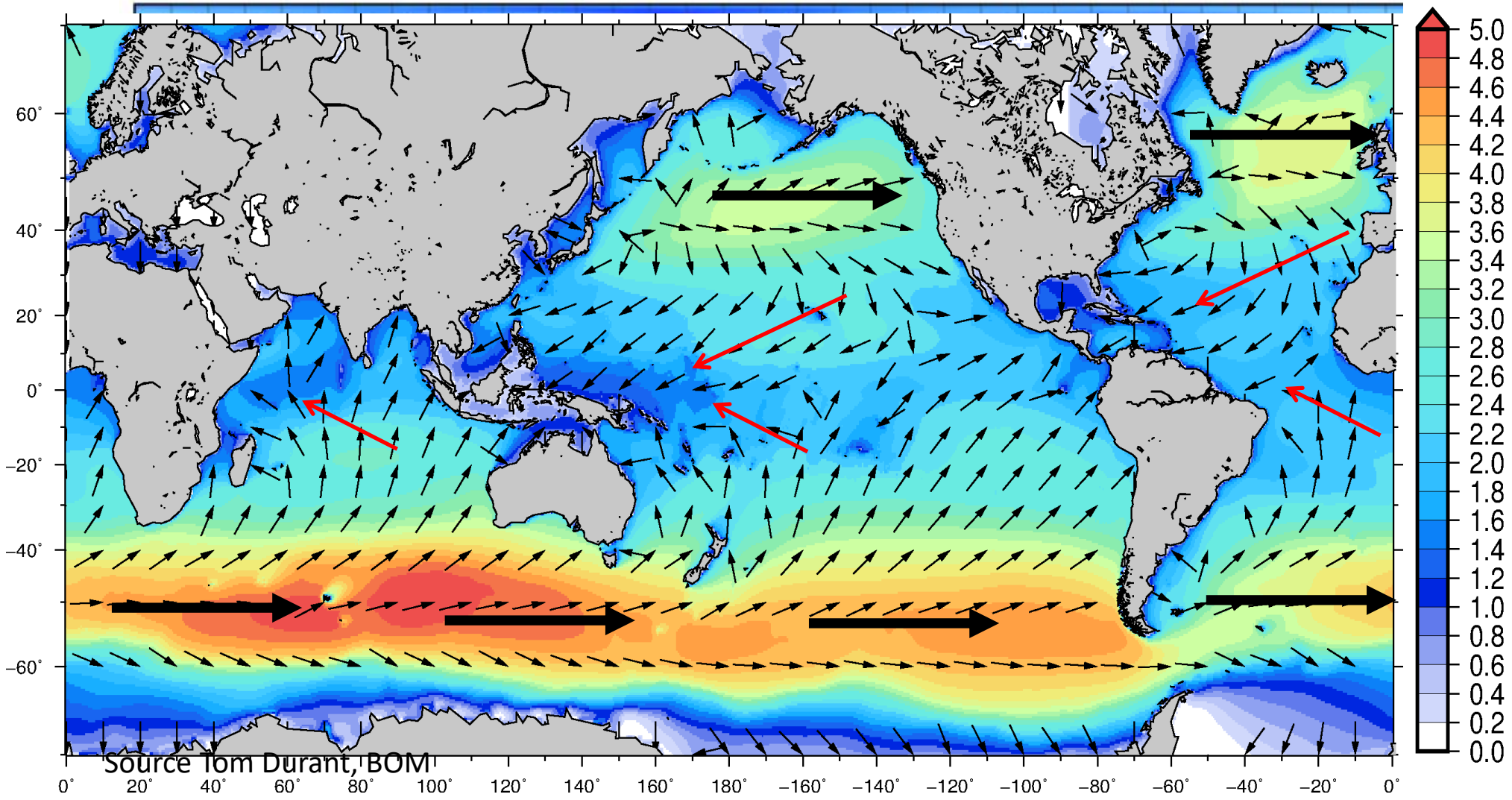
SWELL

Global Wave Climate



1-A) Wave Climate In The Pacific

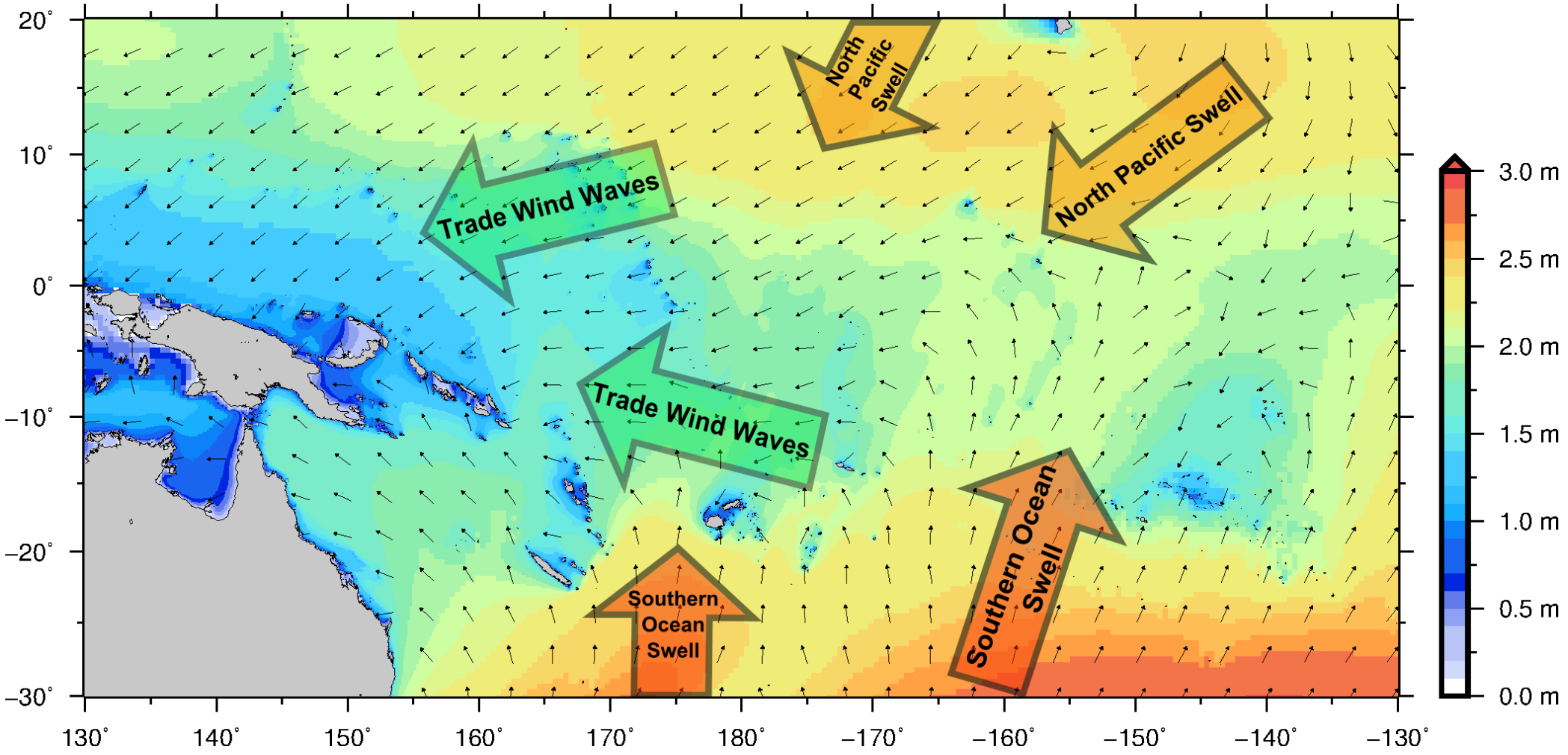
Mean annual wave height and direction



Source Tom Durant, BOM

REGIONAL WAVE CLIMATE

Mean annual wave height and direction



Nearshore Wave Transformation

1) WAVE

- Basic of waves
- Wave climate in the Pacific
- Wave transformation

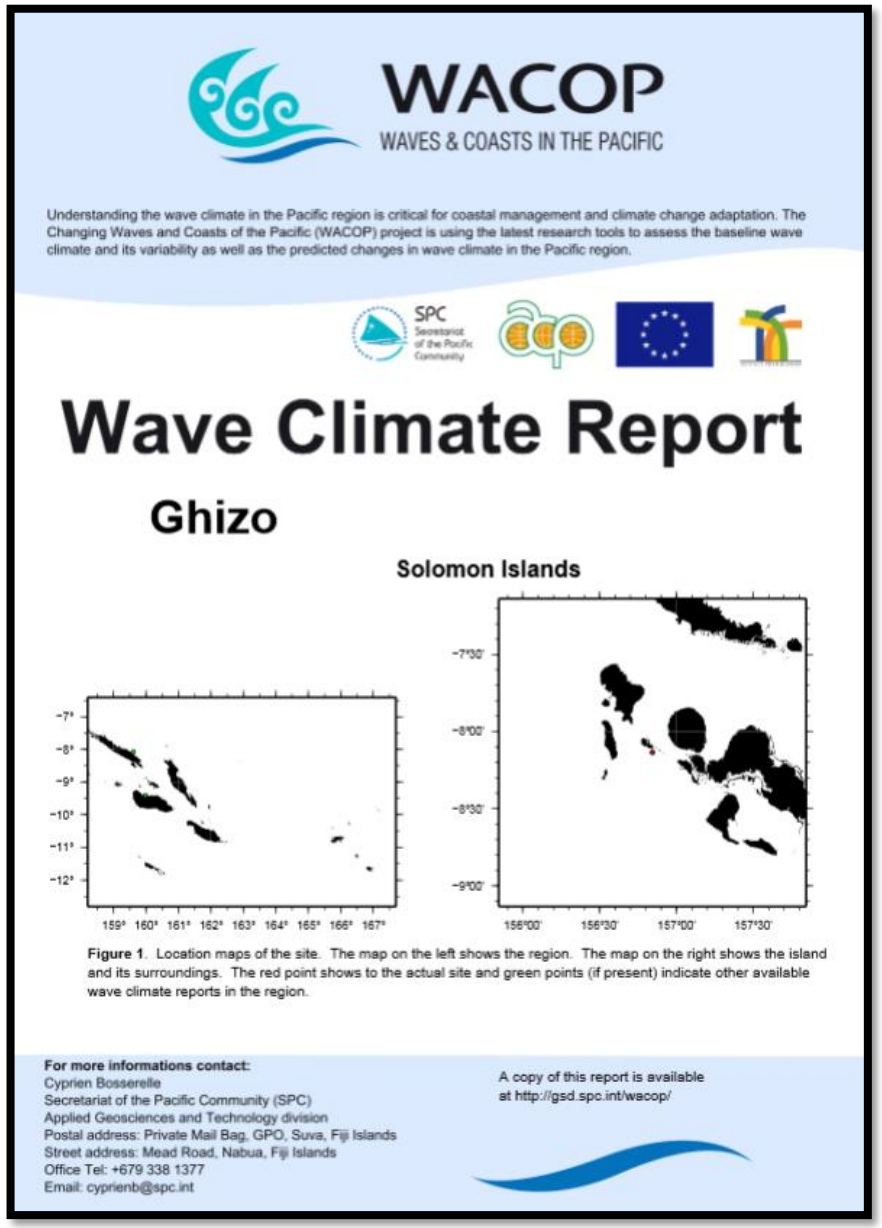
- Refraction, Diffraction
- Shoaling
- Breaking
- Infragravity wave generation

WAVE ATLAS REPORTS

http://gsd.spc.int/wacop/

Includes:

- General Wave climate
- Wave climate variability
- Large and Severe Wave
- Extreme Wave
- Wave Energy
- Wind Climate
- Projected Wave Climate



WACOP

WAVES & COASTS IN THE PACIFIC

Understanding the wave climate in the Pacific region is critical for coastal management and climate change adaptation. The Changing Waves and Coasts of the Pacific (WACOP) project is using the latest research tools to assess the baseline wave climate and its variability as well as the predicted changes in wave climate in the Pacific region.

Wave Climate Report

Ghizo

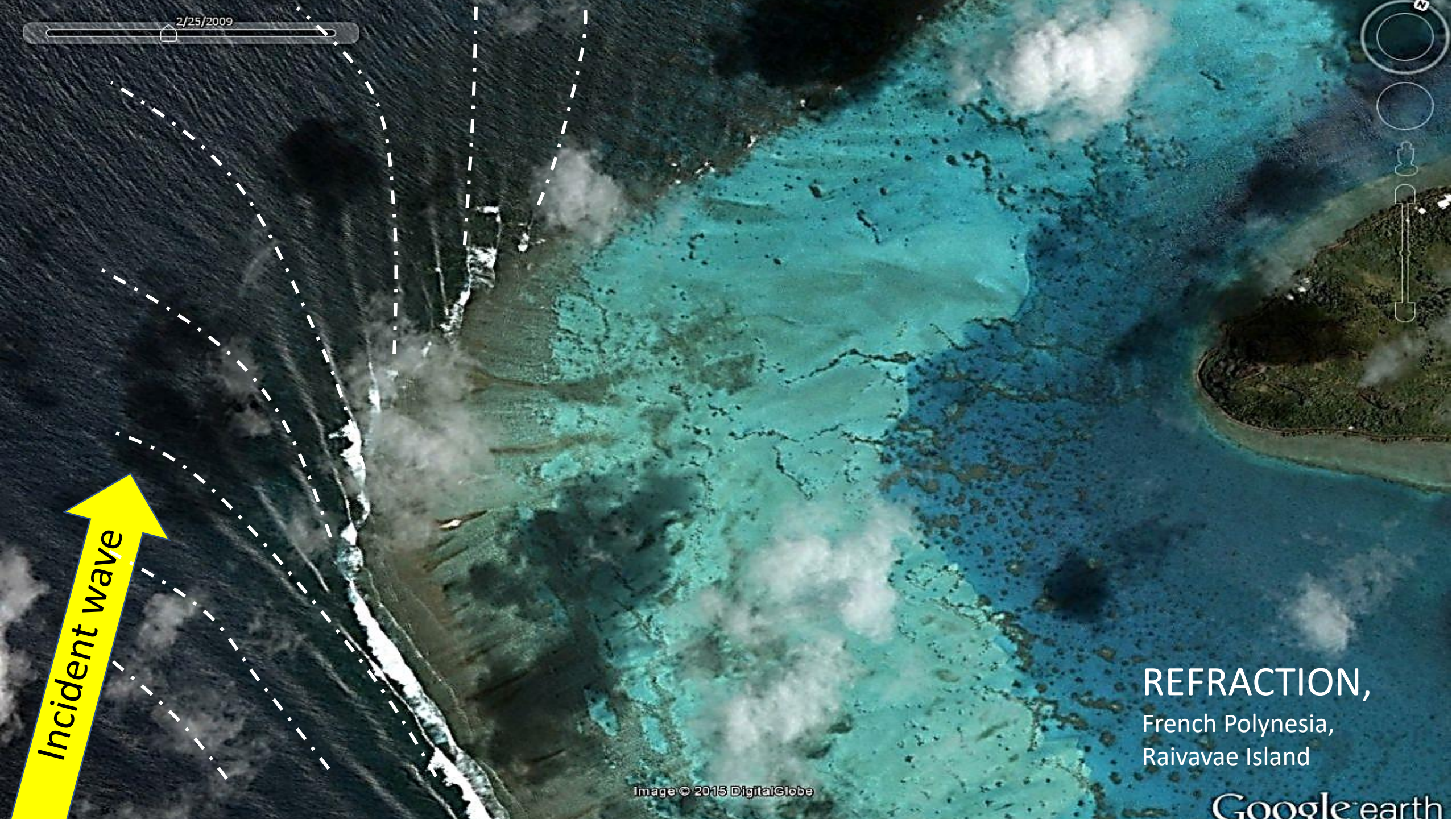
Solomon Islands

Figure 1. Location maps of the site. The map on the left shows the region. The map on the right shows the island and its surroundings. The red point shows to the actual site and green points (if present) indicate other available wave climate reports in the region.

For more informations contact:
Cyprien Bosserelle
Secretariat of the Pacific Community (SPC)
Applied Geosciences and Technology division
Postal address: Private Mail Bag, GPO, Suva, Fiji Islands
Street address: Mead Road, Nabua, Fiji Islands
Office Tel: +679 338 1377
Email: cyprienb@spc.int

A copy of this report is available at http://gsd.spc.int/wacop/

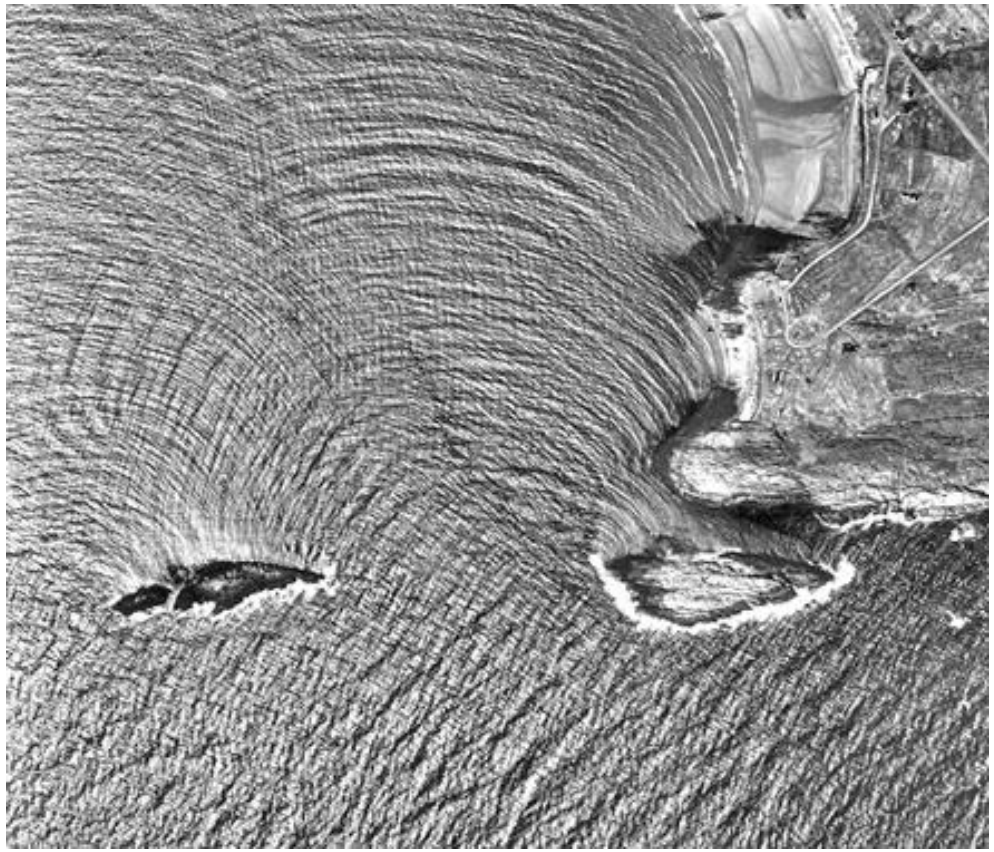

Incident wave
REFRACTION,


2/25/2009
Incident wave
Image © 2015 DigitalGlobe
REFRACTION,
French Polynesia,
Raivavae Island
Google earth

Nearshore Processes: DIFFRACTION

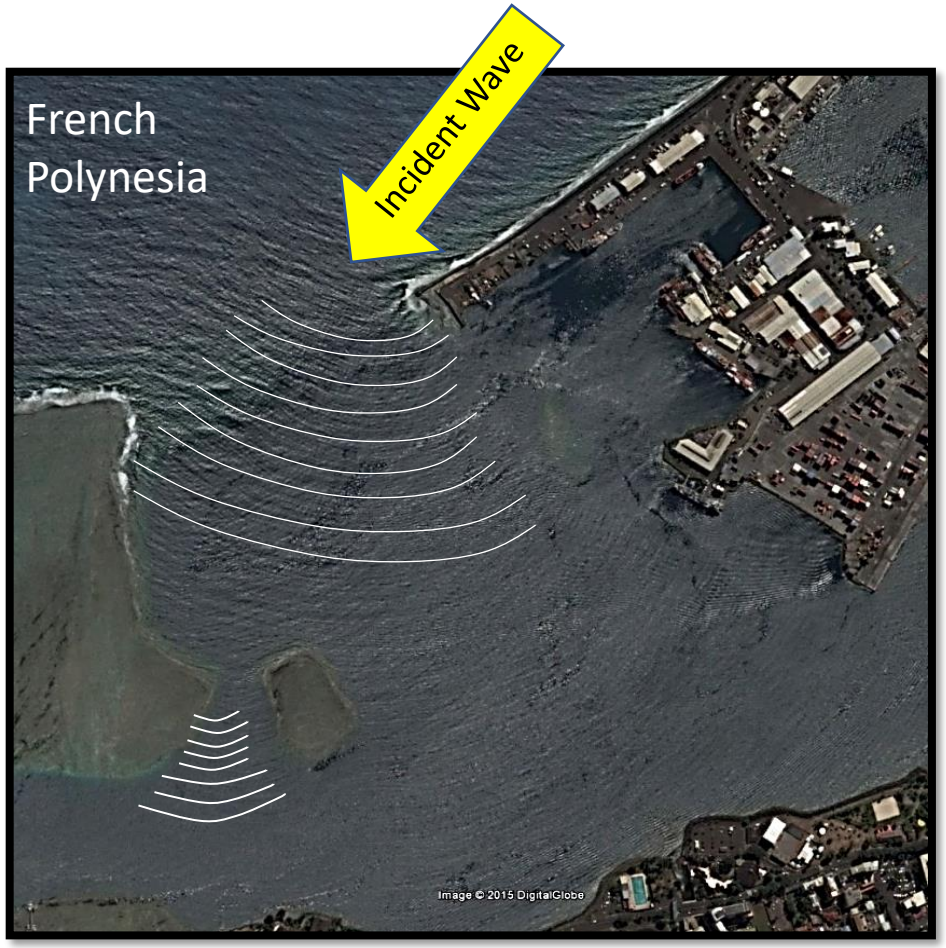
Diffraction:

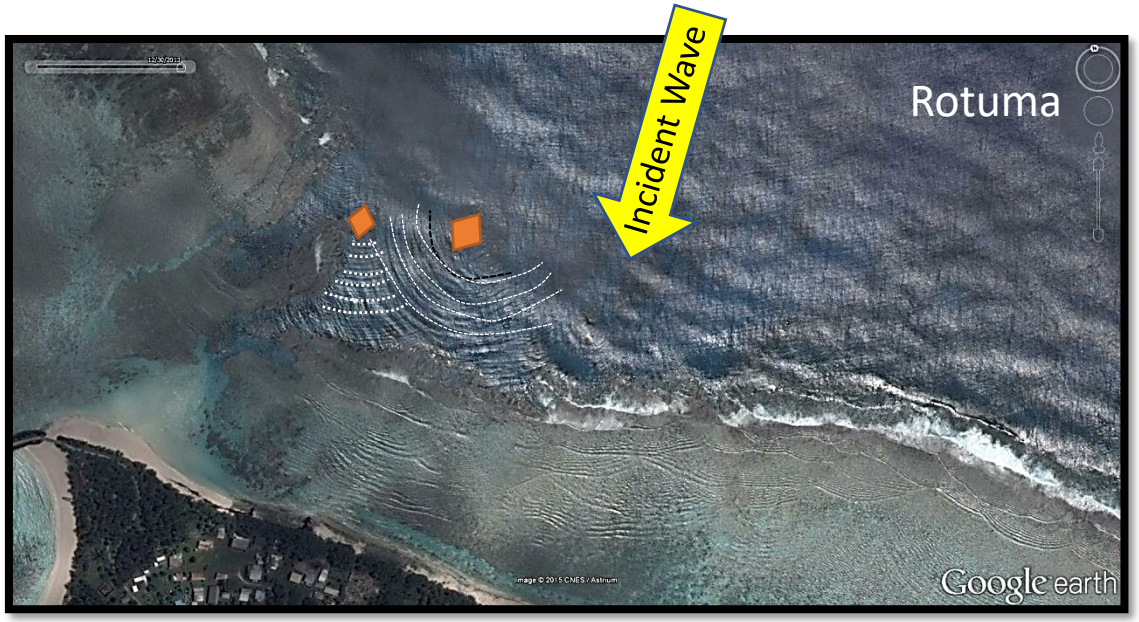
- Wave hit an obstacle (e.g. emerged/shallow water reef) or travels through a small gap (e.g. in-between two islands)
- Wave energy is transferred laterally along the wave crest
- Important for ports, harbor designs

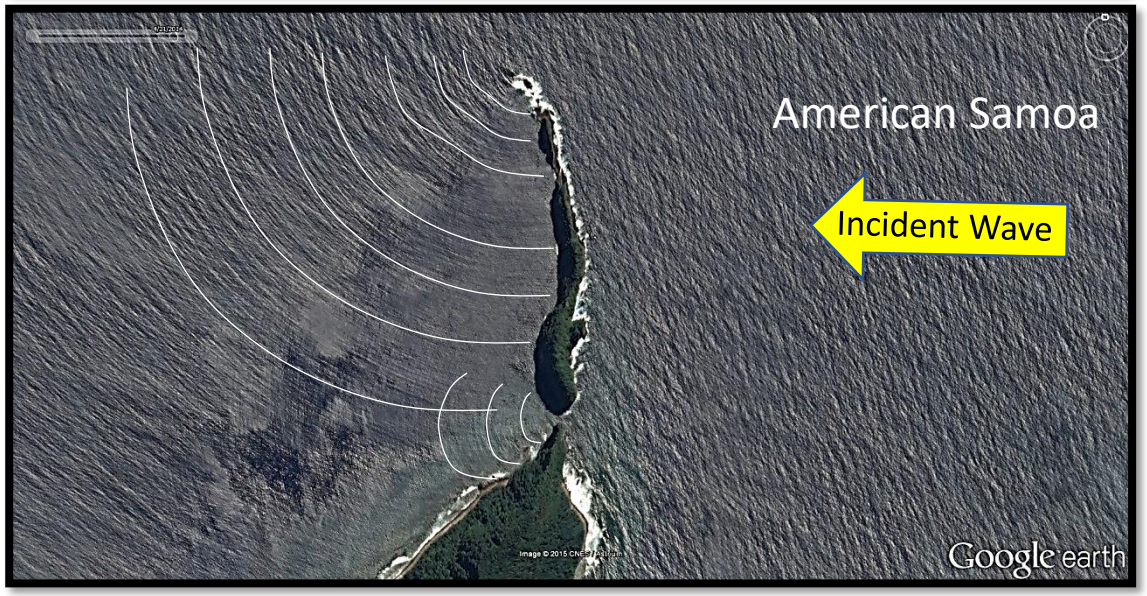


NEARSHORE PROCESSES: DIFFRACTION

Pacific Islands examples of Diffraction



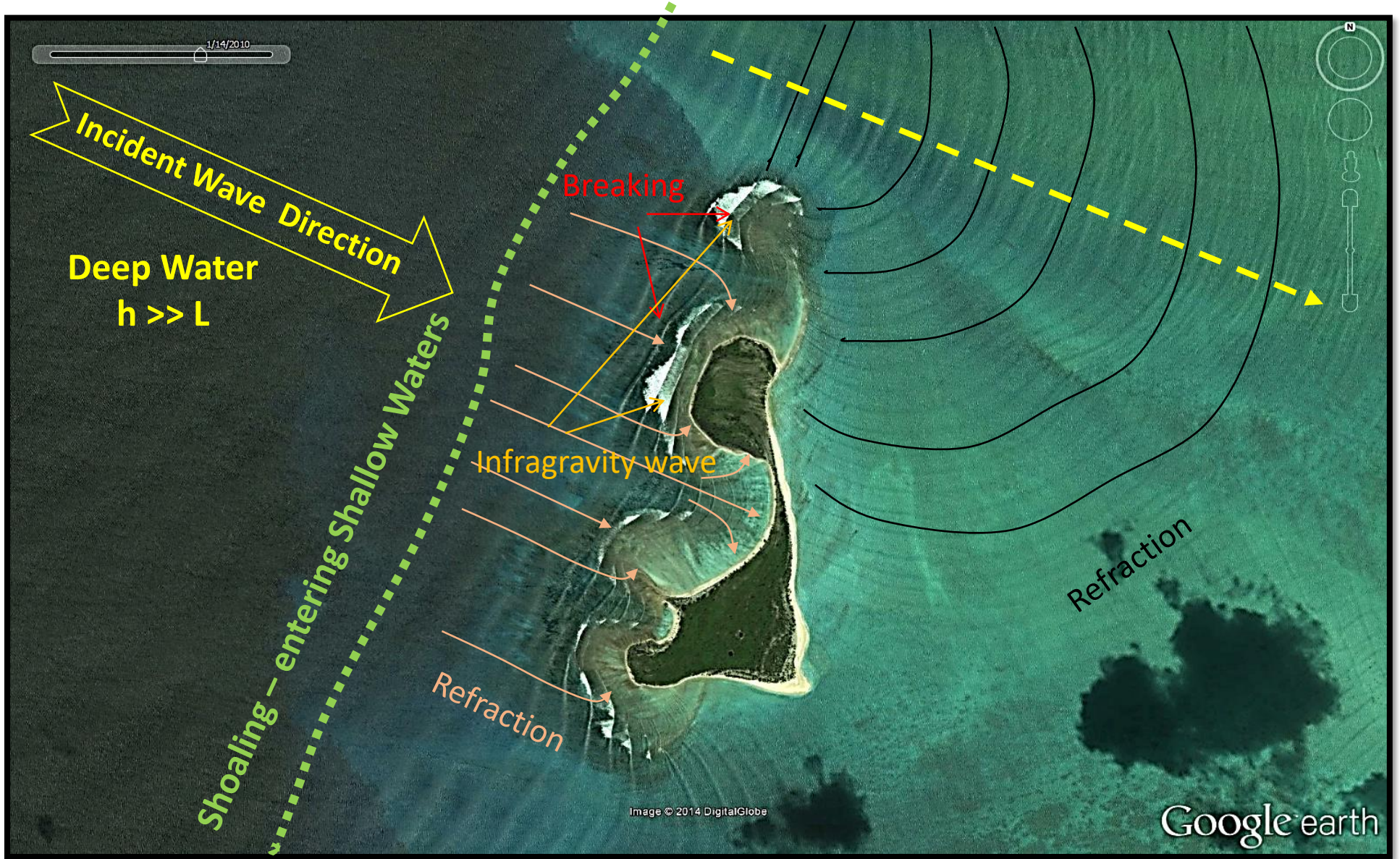




Nearshore Processes:
SHOALING & BREAKING

Shoaling and breaking in Tavarua, Fiji

Nearshore Processes: Wave Transformation



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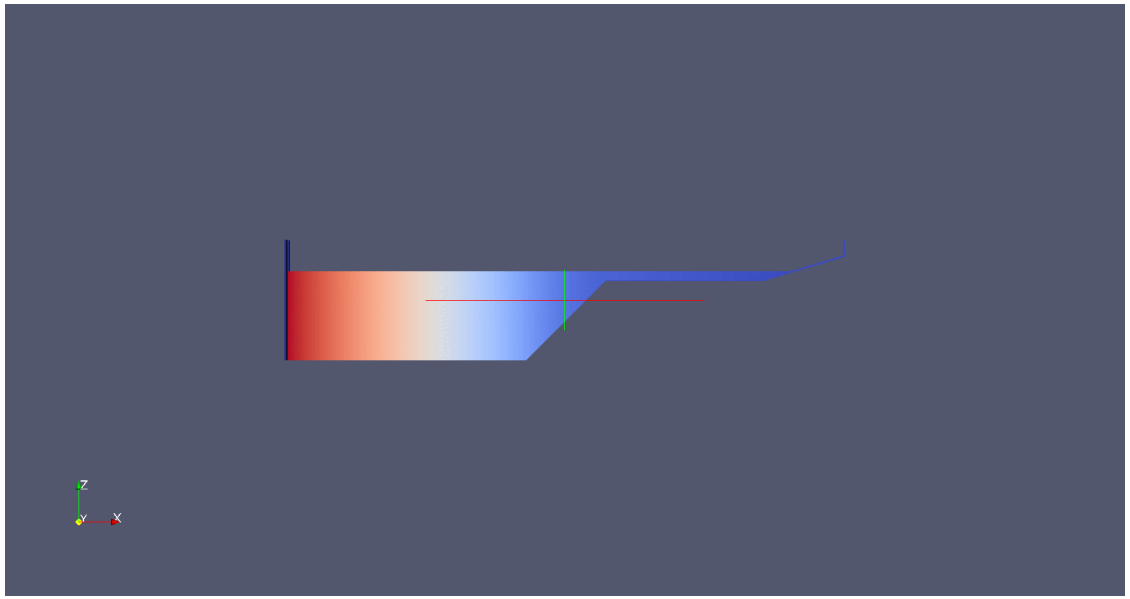

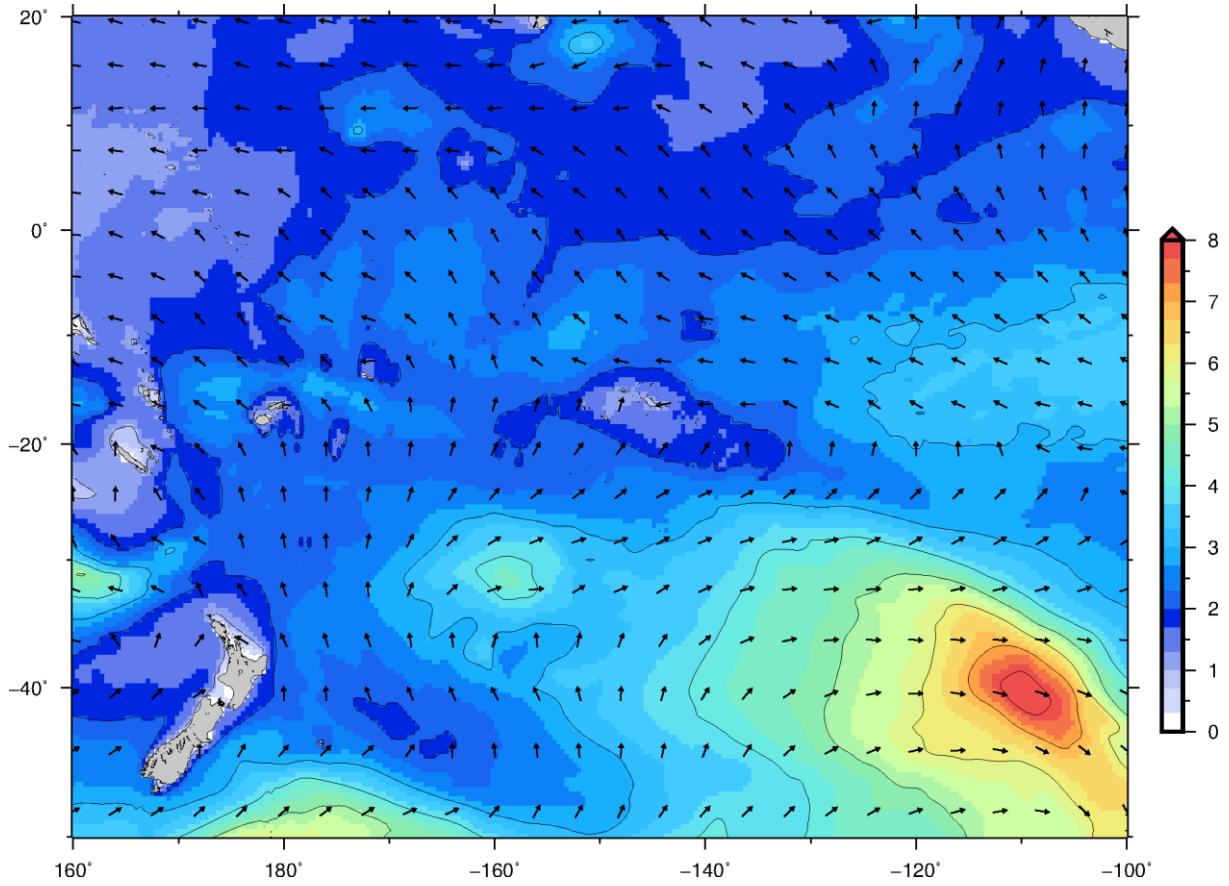

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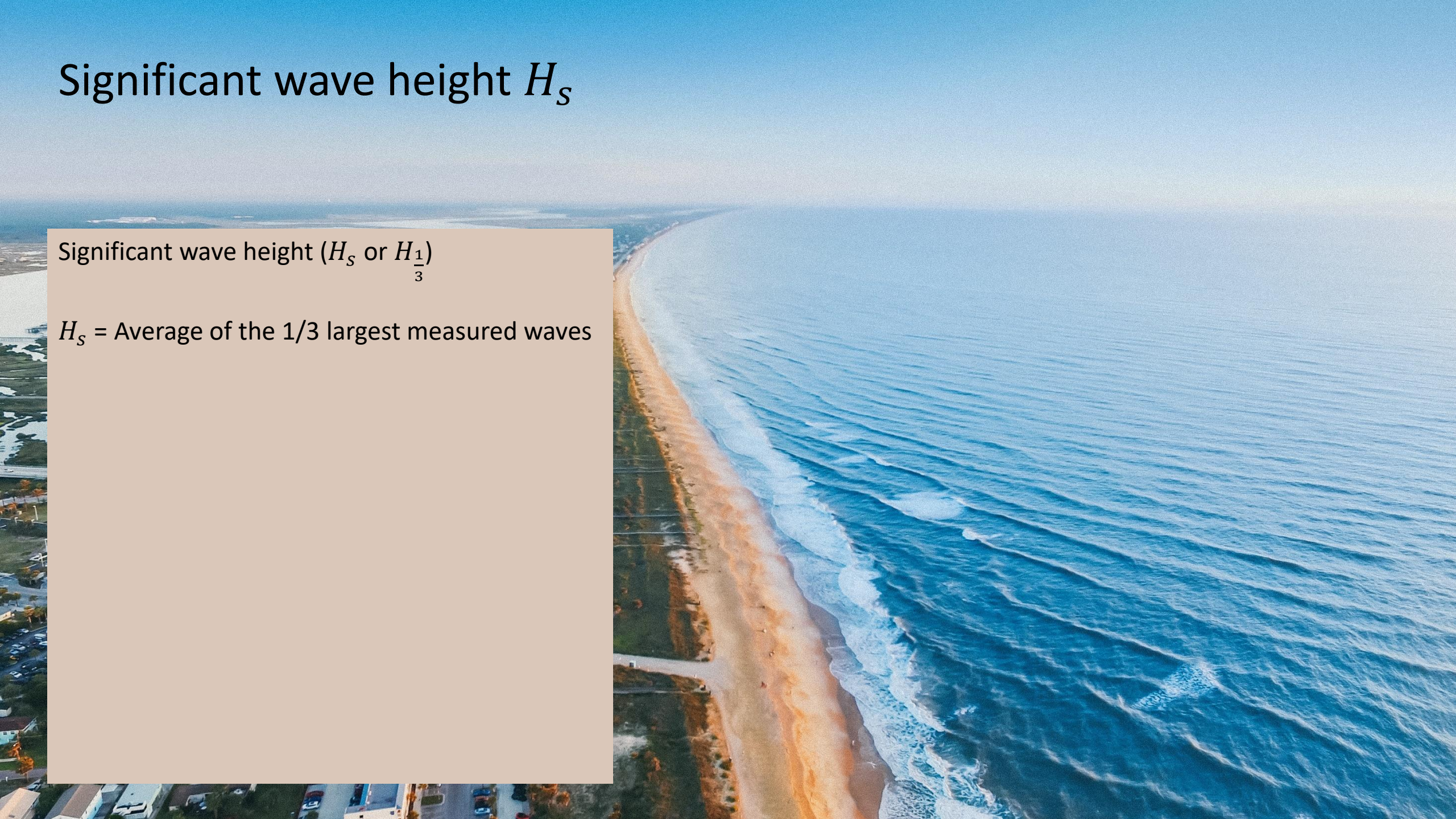

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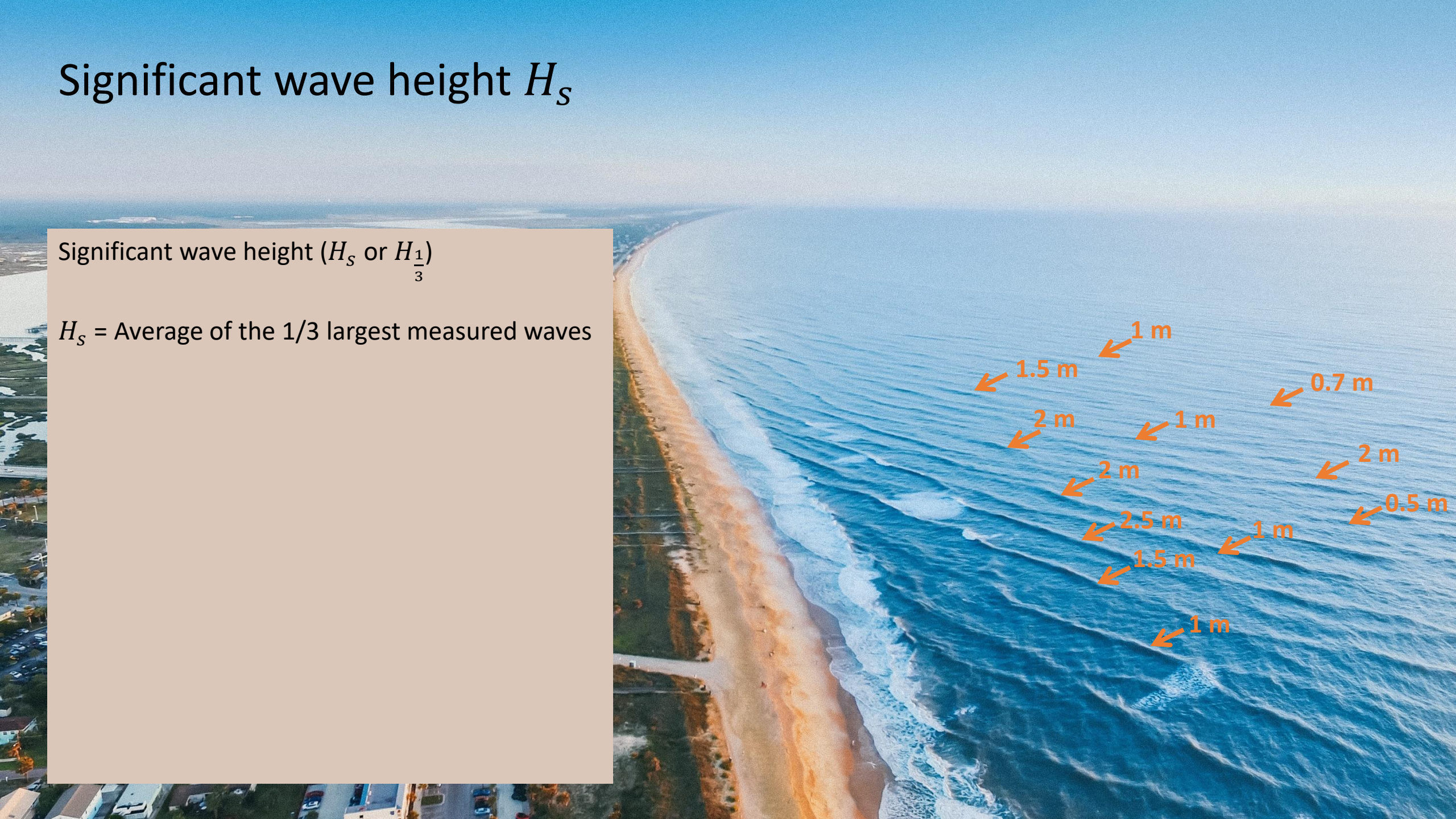

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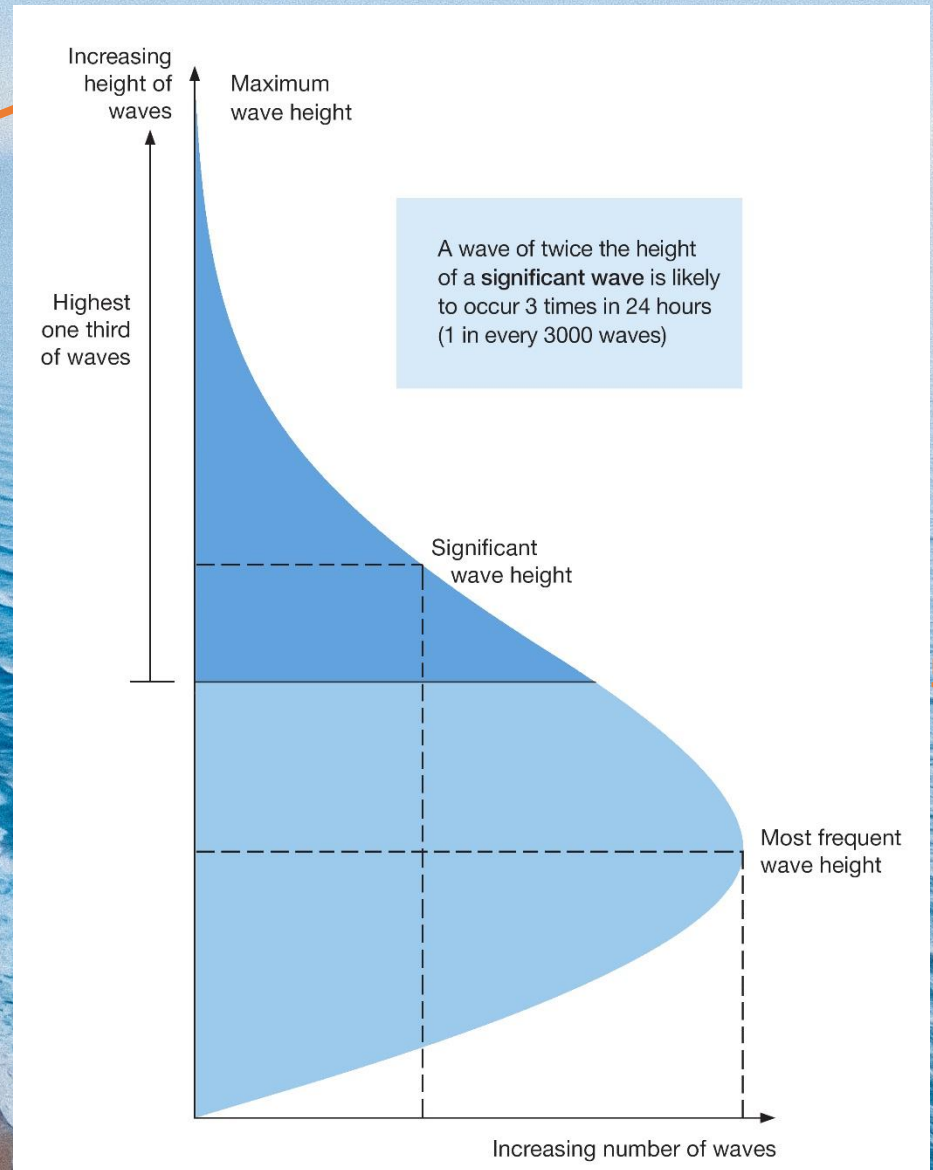
Matches a human‘s perception of the sea state

www.bom.gov.au

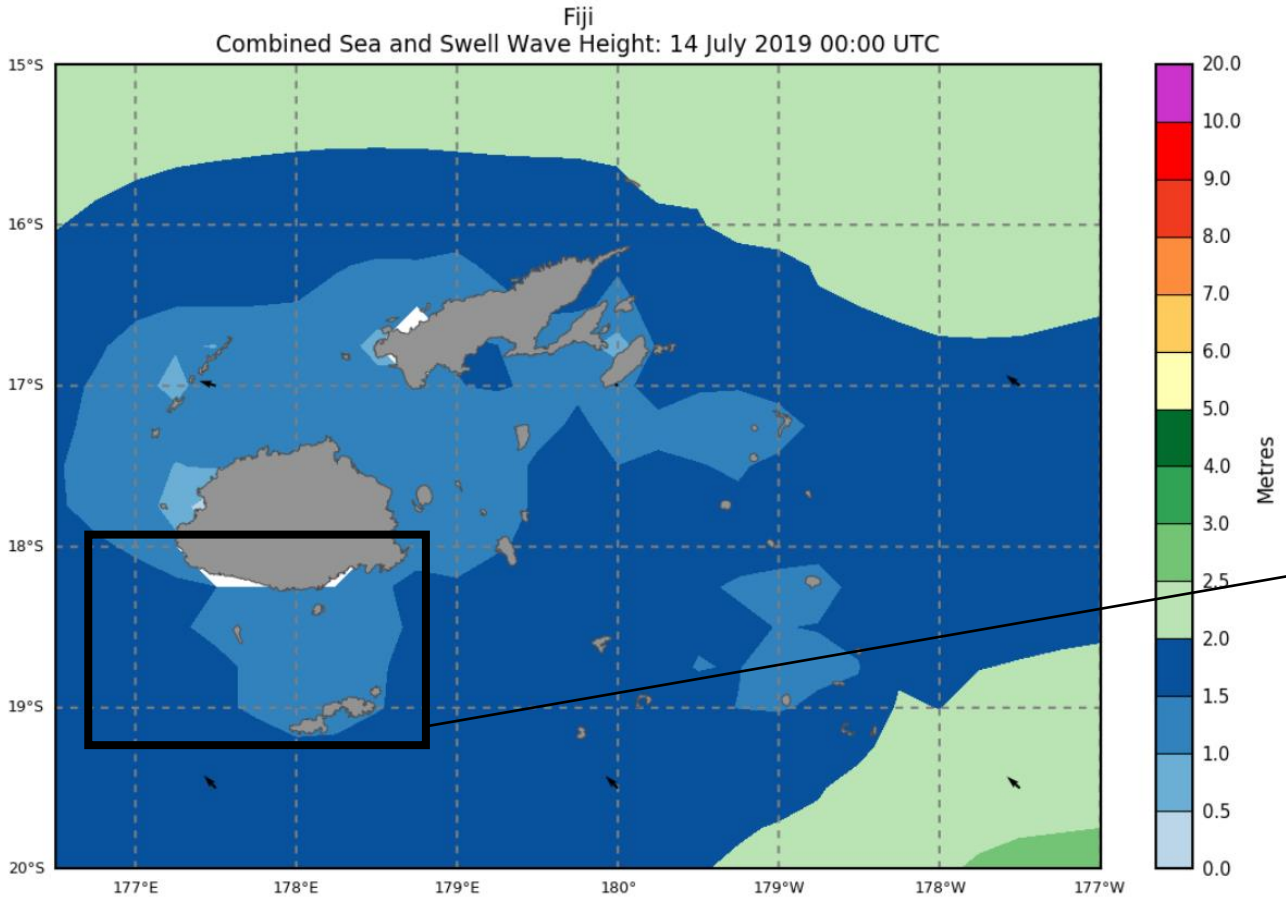


Wave Models for training purposes

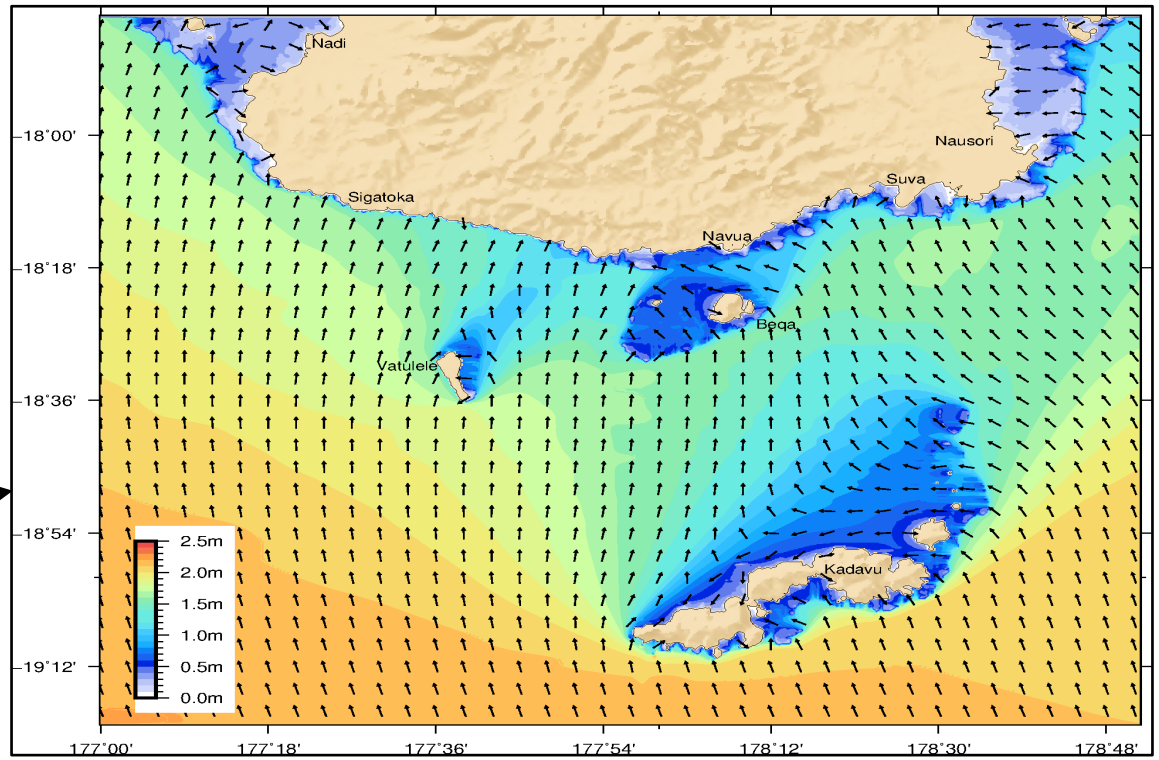
Country	Models Grid Size
RMI	
National	2km
Majuro	450m
Palau	
National	2km
Area A	500m
Area B	500m
Kiribati	
Sub Regiomal Tarawa	2km
Sub Regiomal Kirimati	2km
Tarawa	100m
Kirimati	500m
Solomon	
National	2km
Honiara	250m
Gizo	250m

Global to local information

Coarse resolution: 10s of kms



Fine resolution: 100s of metres



Swan Wave Model

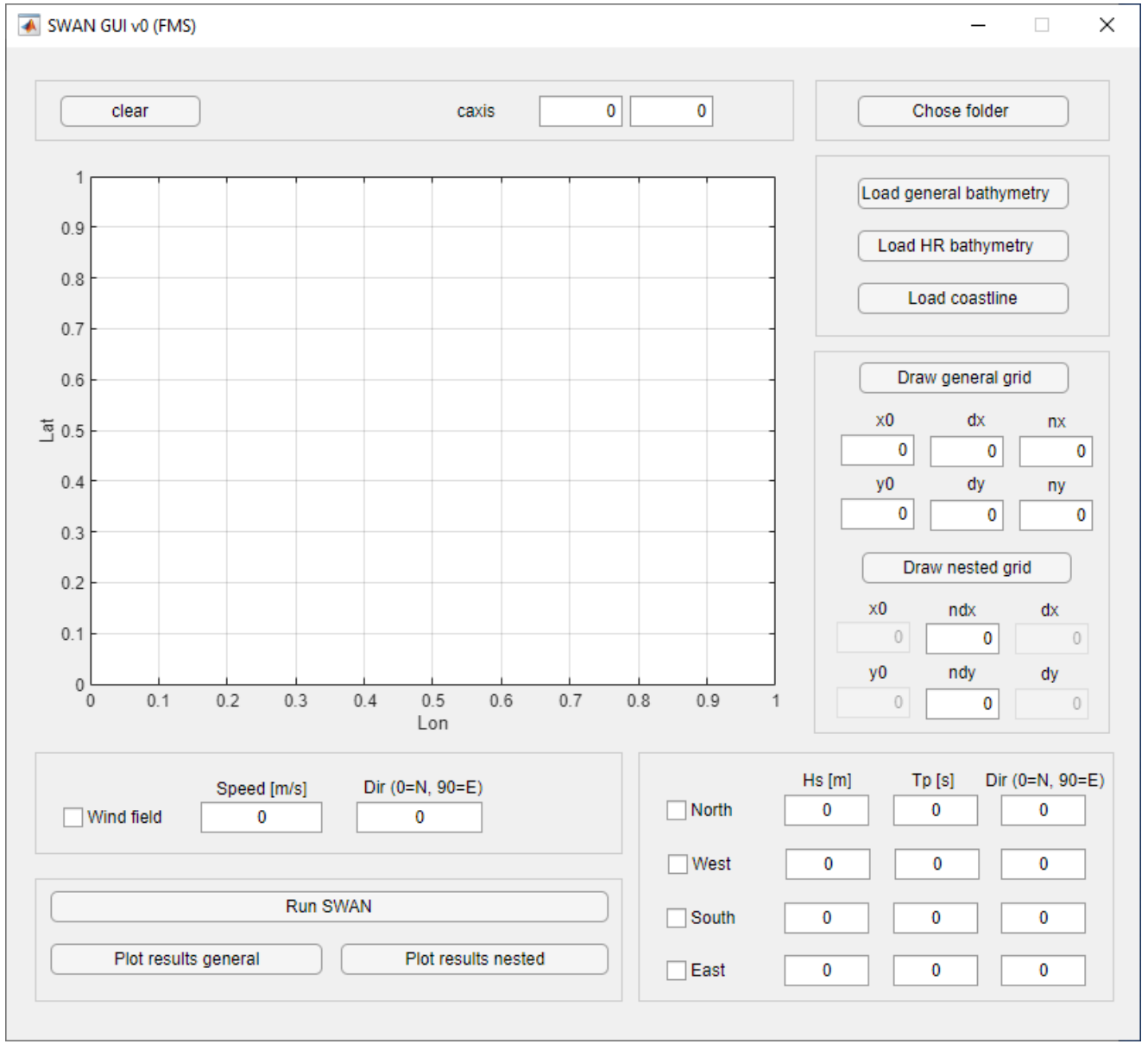
Graphical user interface - manual

Wave model (SWAN) GUI

1. Easy to install: Executable (.exe)

2. Organised through a fixed folder structure

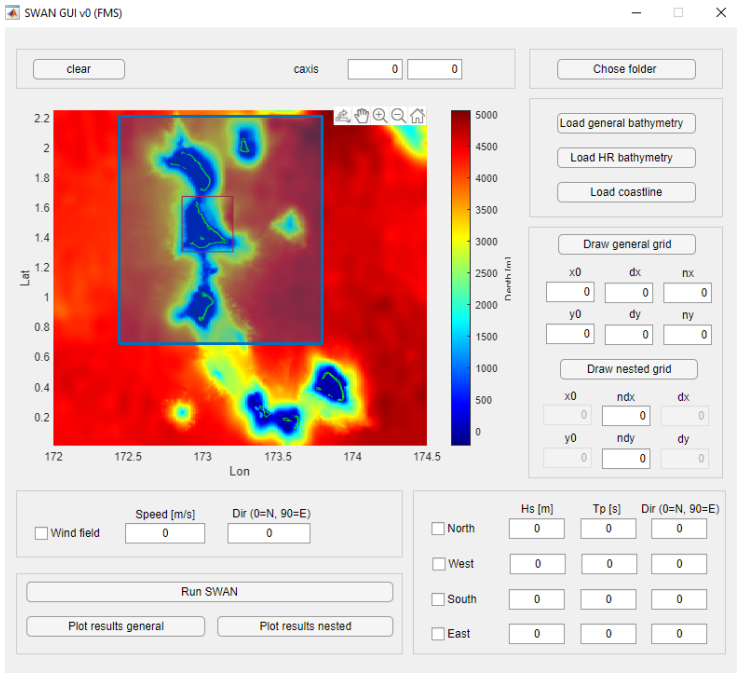
   - bathymetries
   - cases
   - coastline
   - GUI
   - runs
   - swan_files
   - swan_manuals

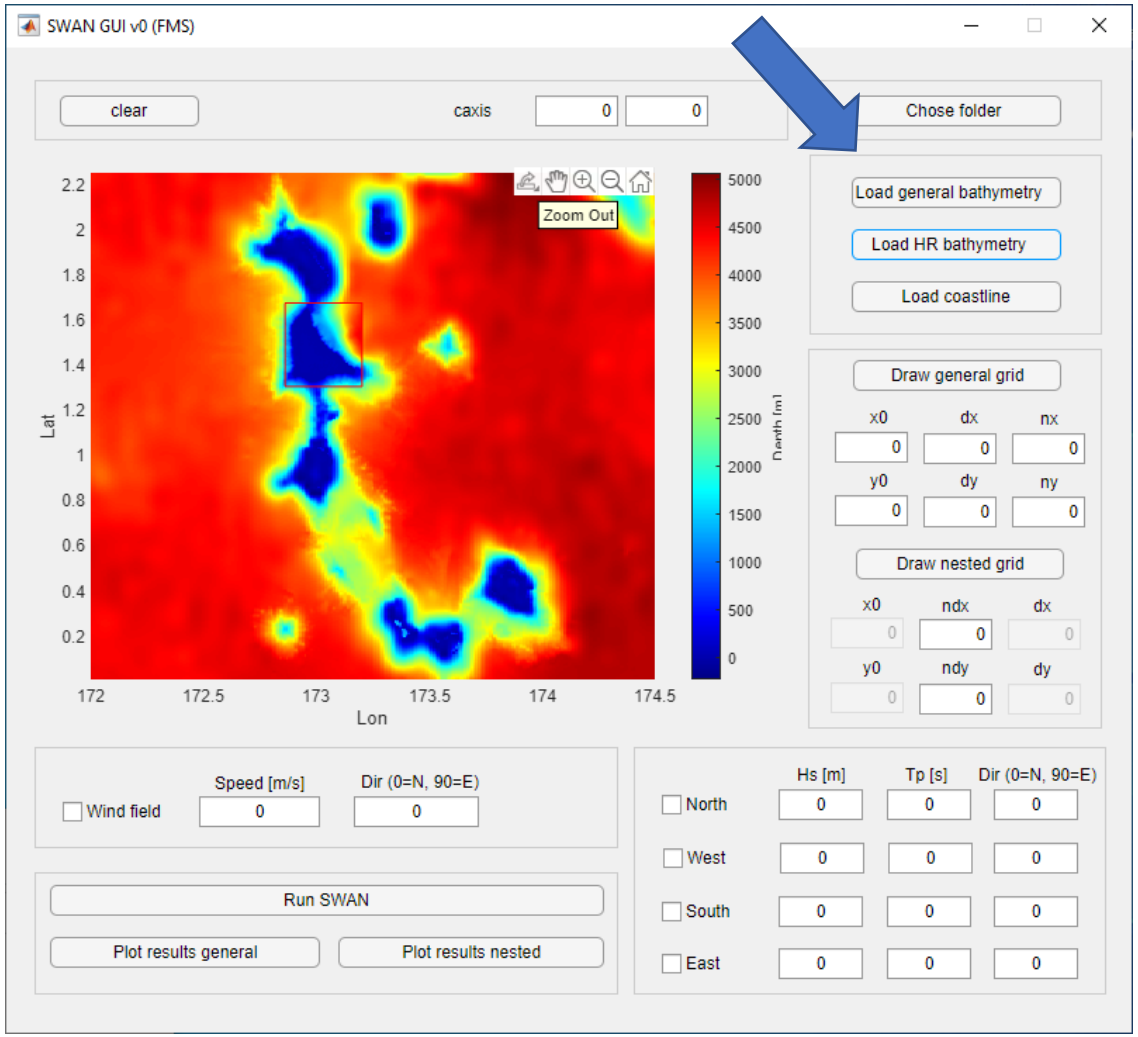


Wave model (SWAN) GUI

- The GUI supports the importing of a maximum of two bathymetry datasets (with identical projection), a global and a high resolution datasets.
- **Load Coastlines**

- **Flexible computational domain, Automated nesting capability.**



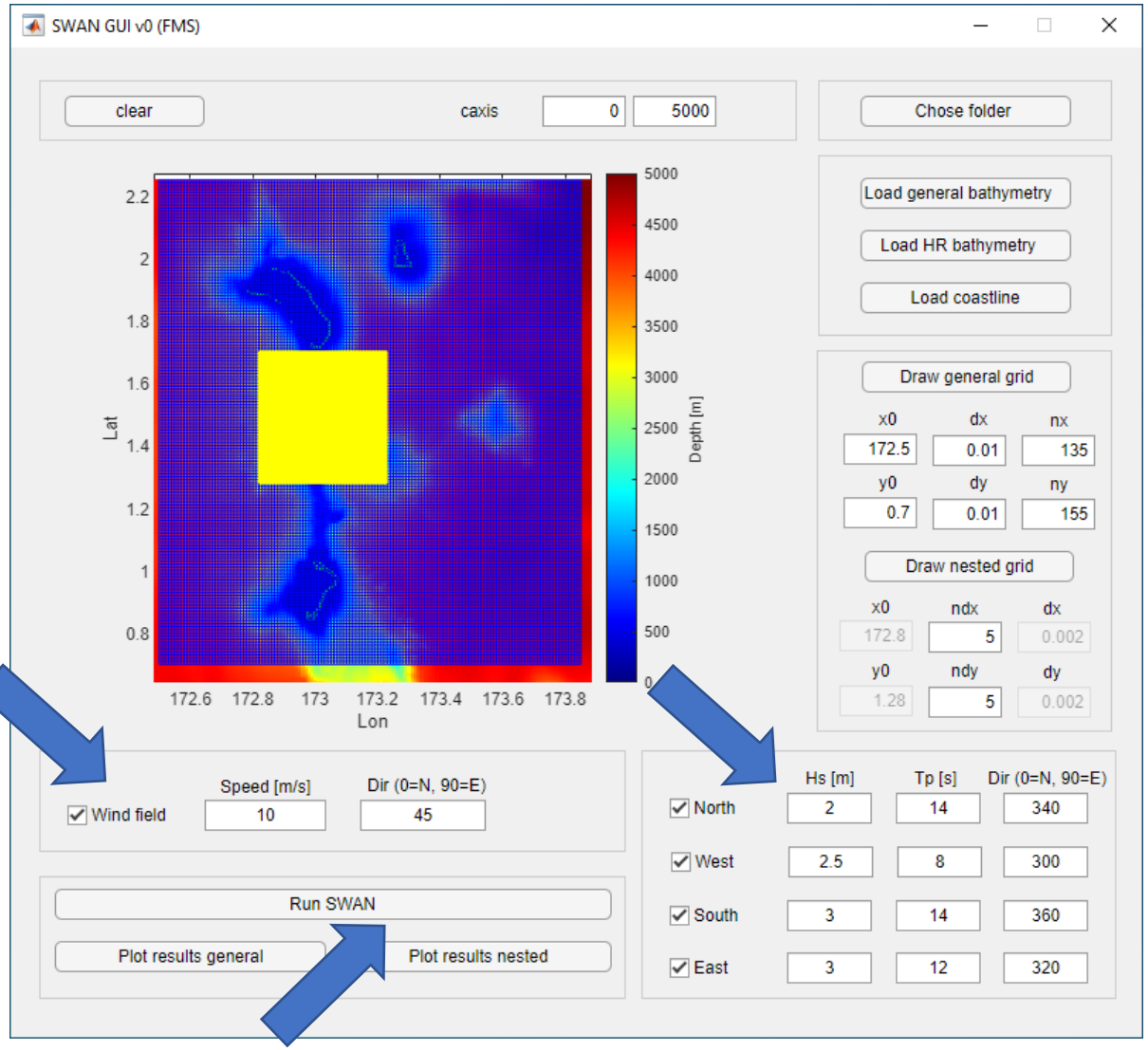


Wave model (SWAN) GUI

- Define wave boundary conditions for each side of the general grid
  - Hs: significant wave height
  - Tp: Peak period
  - Dir: Mean direction

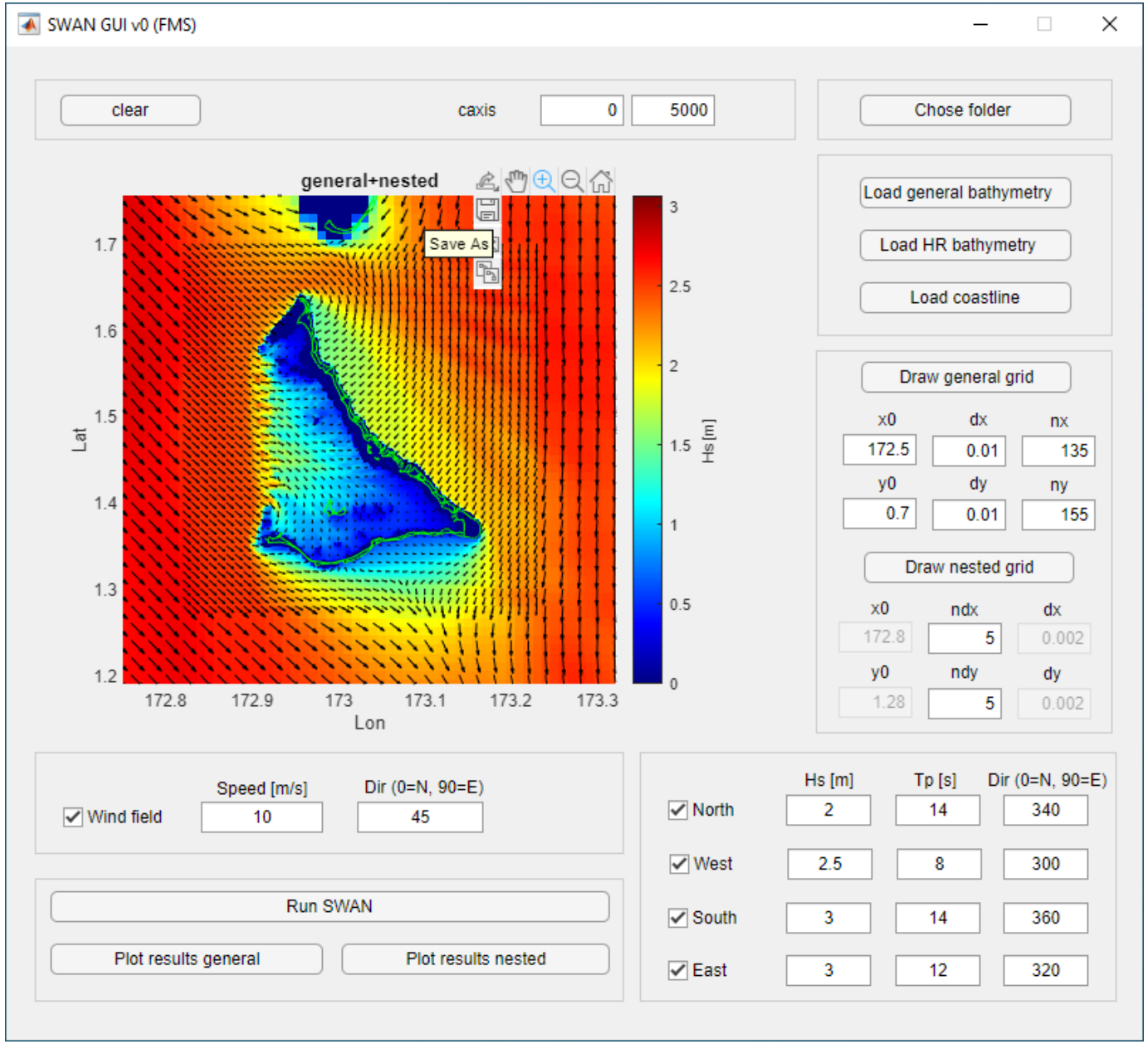
- Define constant wind
  - Speed
  - Direction

- Run SWAN button: Use to start the model run



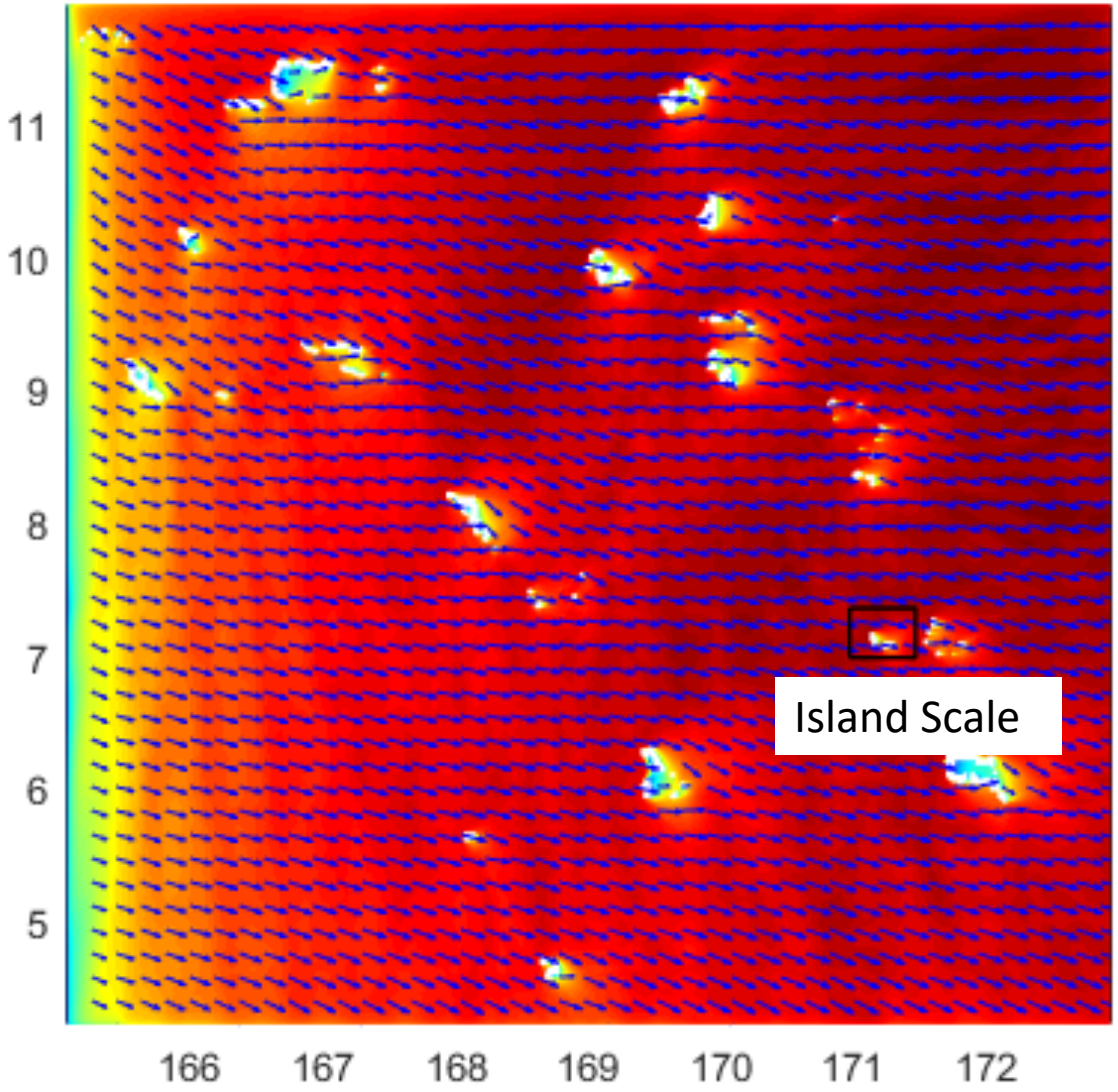
Wave model (SWAN) GUI

- **Plot result general** button: Use to plot the result from the general wave model as a 2D map of the wave height and direction.
- **Plot result nested** button: Use to plot the result from the HR wave model as a 2D map of the wave height and direction.
- The colorbar can be adjusted (Caxis) to better represent wave gradients in the area of interest.
- The result can be exported as …

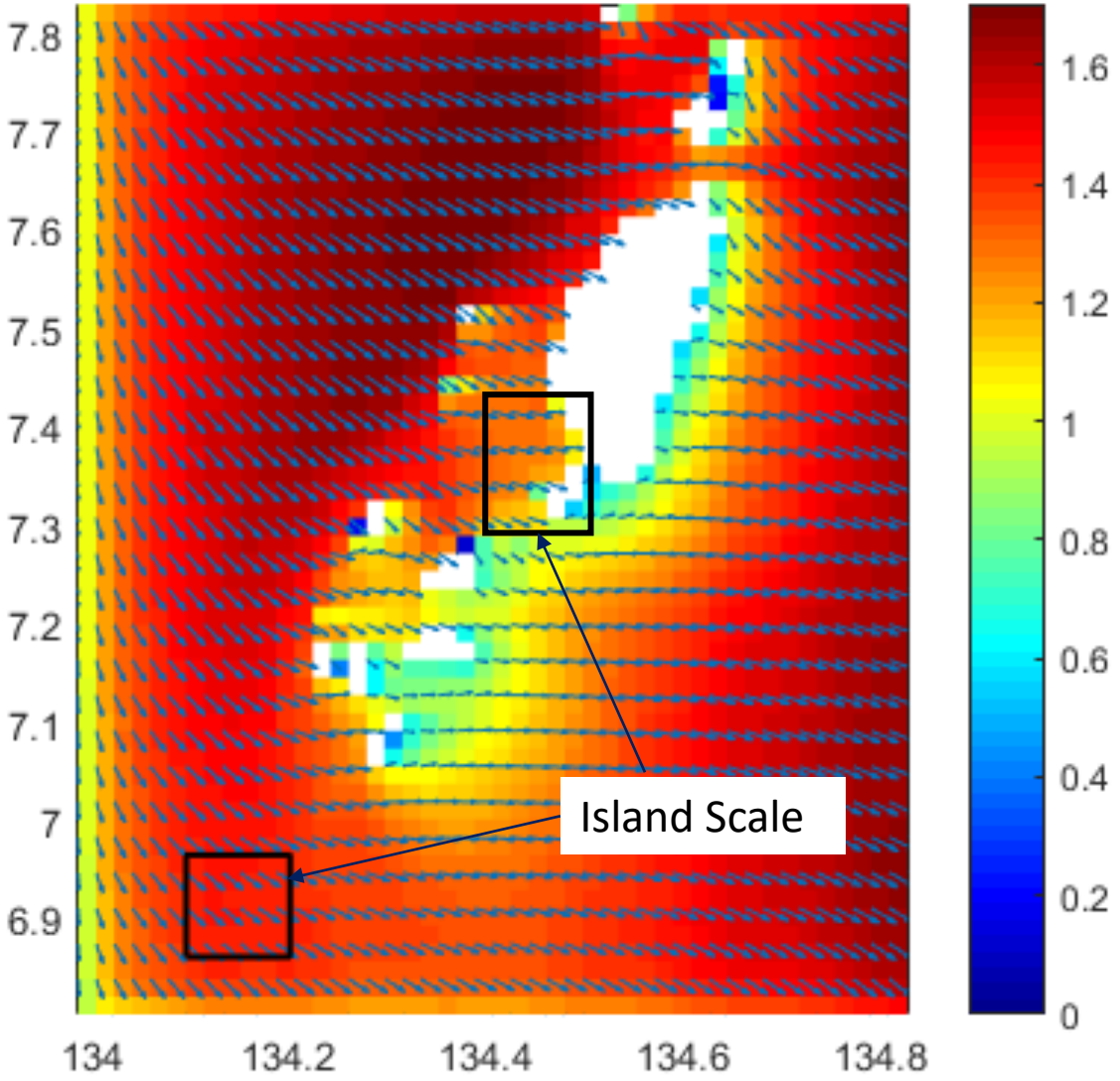


RMI

National Scale

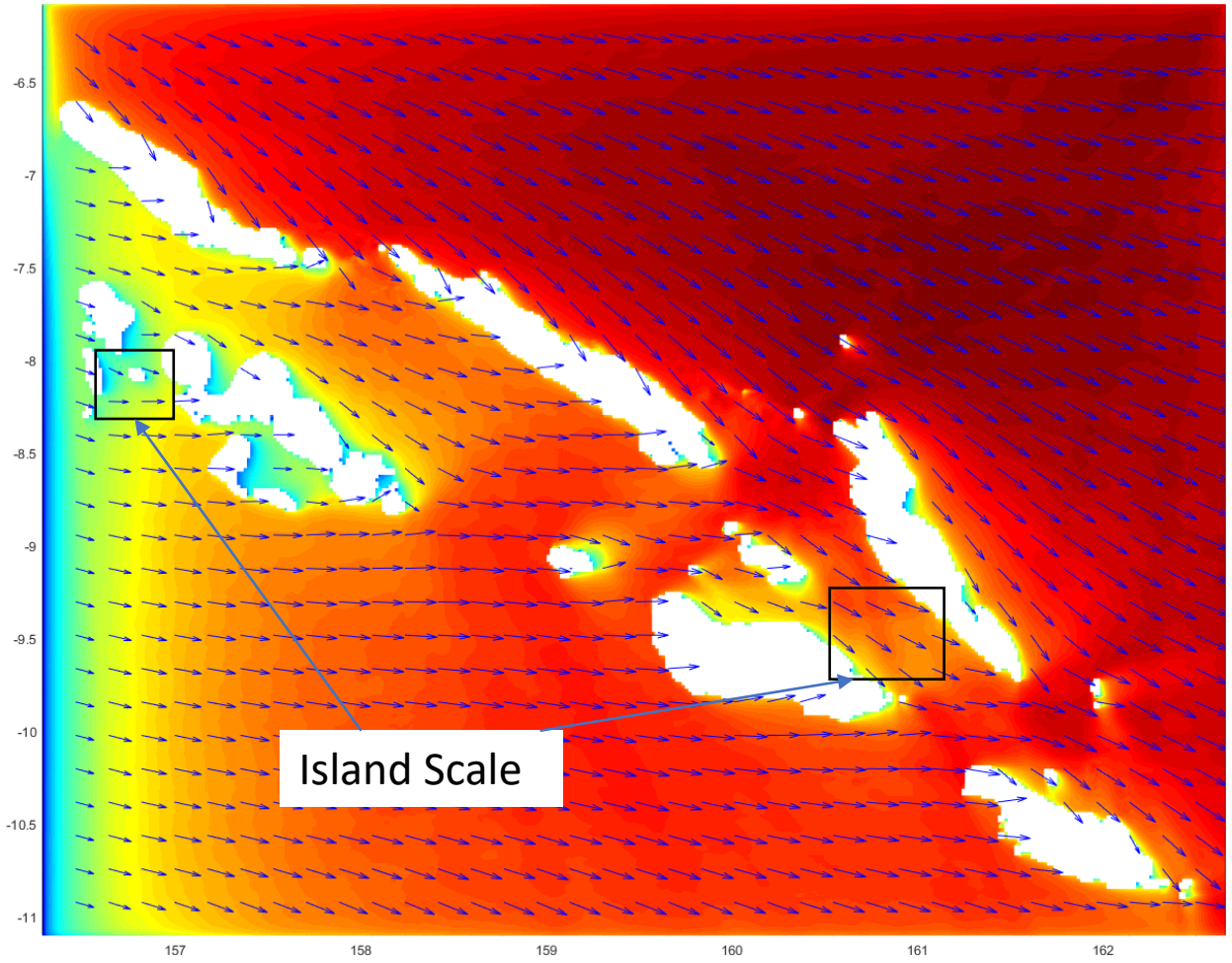


Palau

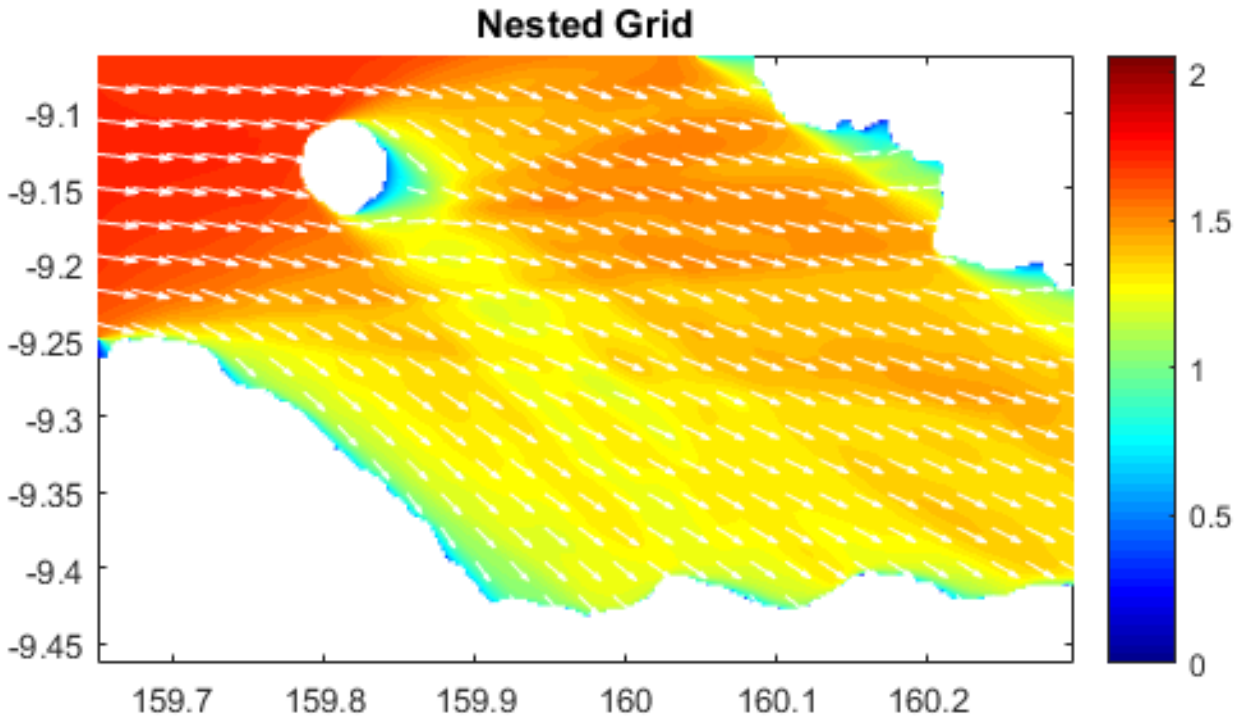


Solomon(Honiara)

National Scale

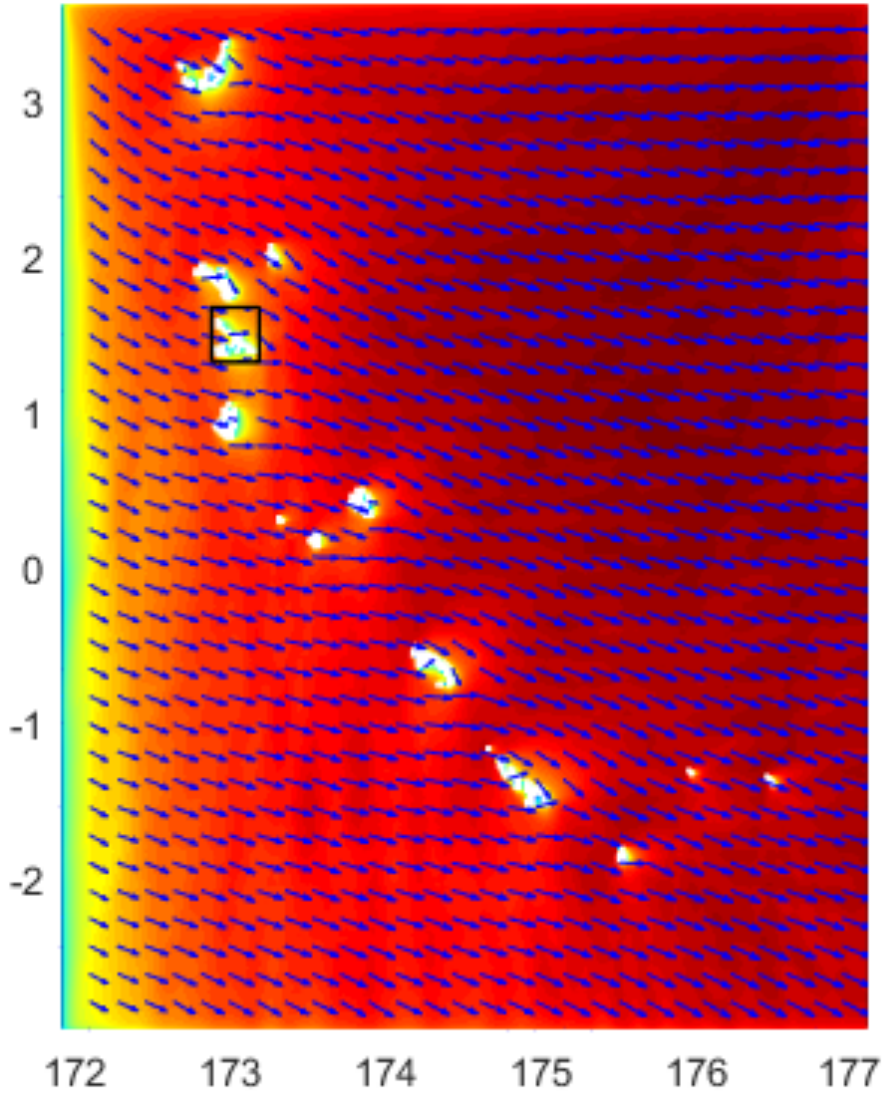


Guadalcanal/Honiara

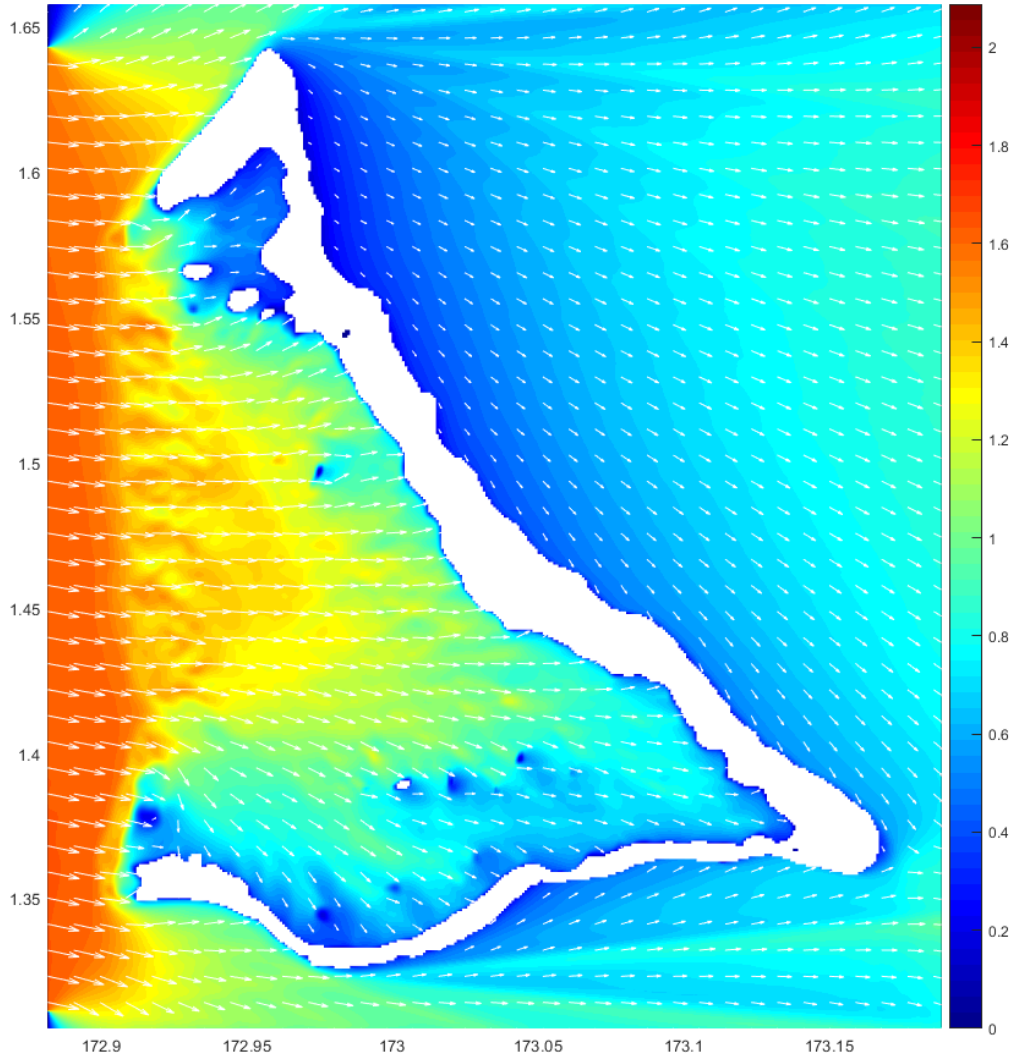


Kiribati (Tarawa)

National Scale (Gilbert Islands)



Island Scale



How could this tools and capacity be used:
- In your country?
- In your line of work?
- In upcoming projects?

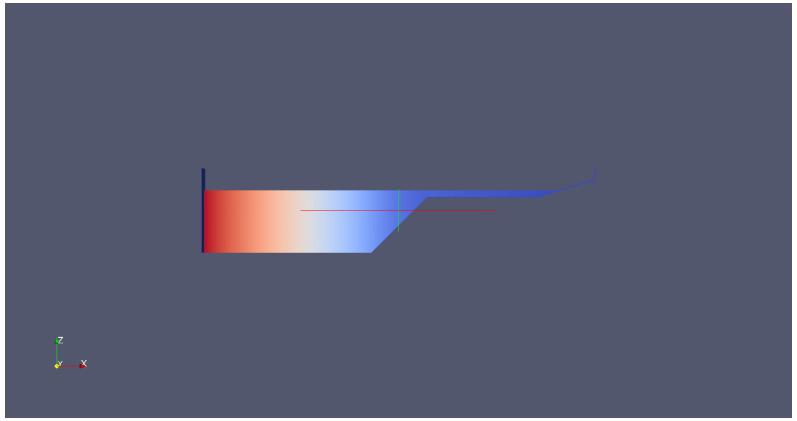
Recap

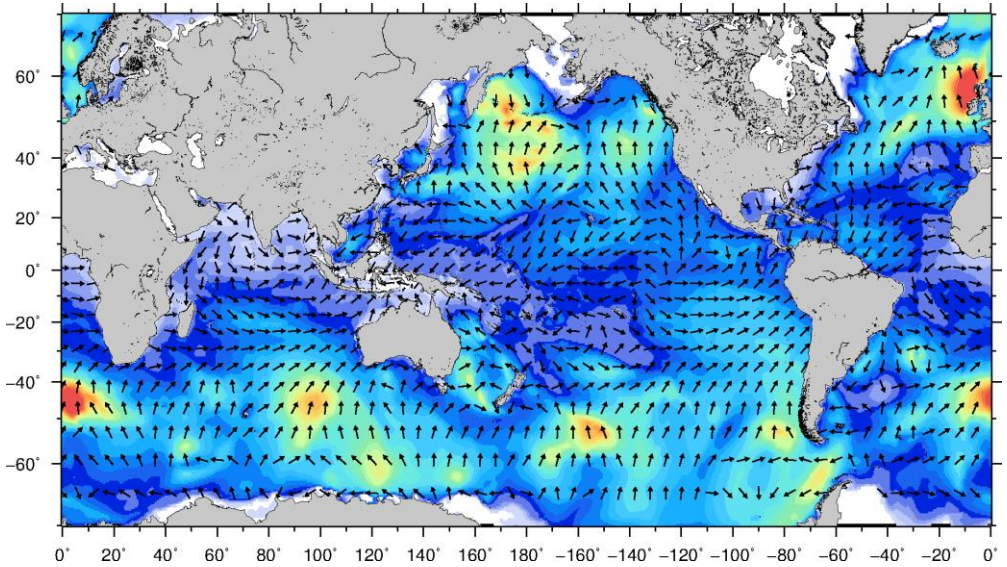
- Under the CTCN project, the project team produced a flexible user interface to easily develop wave models and see the results
- The GUI was used to create national and island scale wave models for the participating countries
- Wave models can be improved as better baseline data are made available

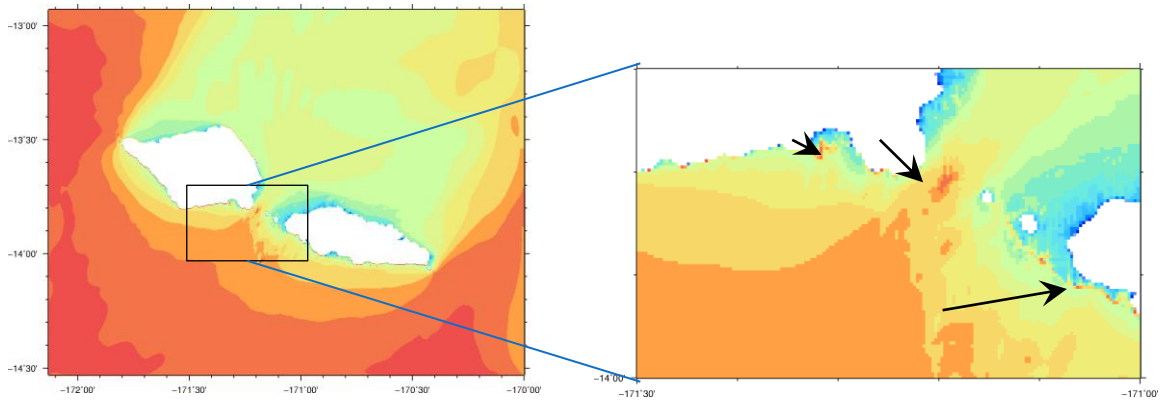
WAVE MODEL TUTORIAL

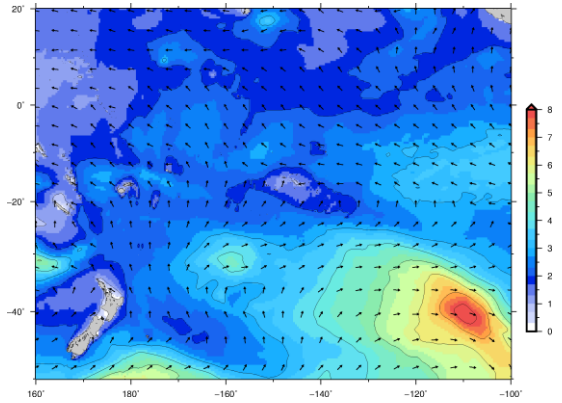
Pacific Community
Communauté du Pacifique

INTRODUCTION TO WAVE MODELLING









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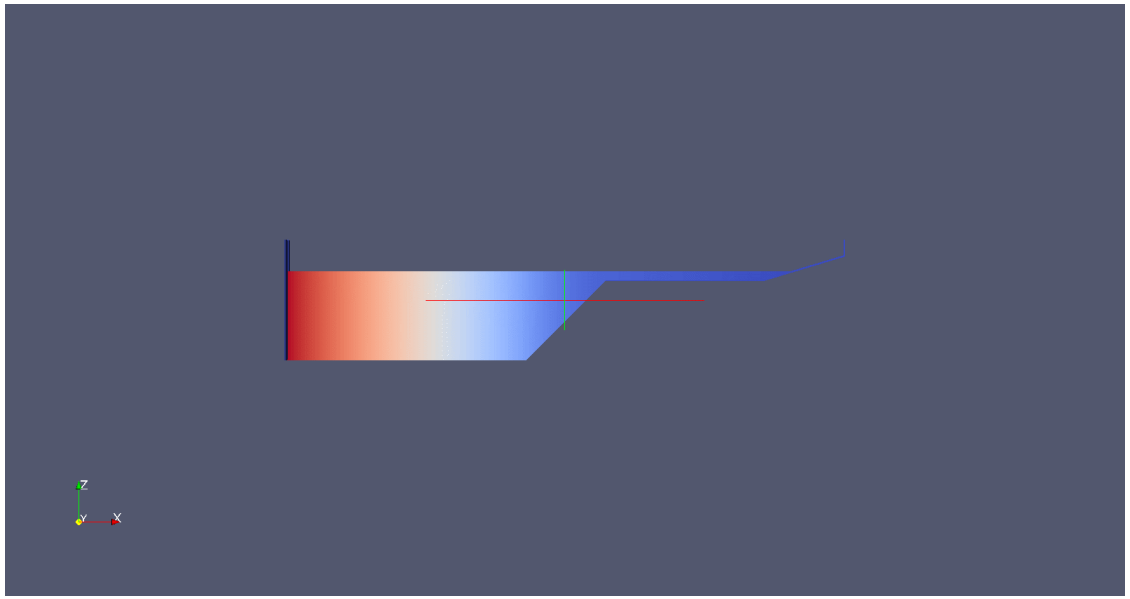

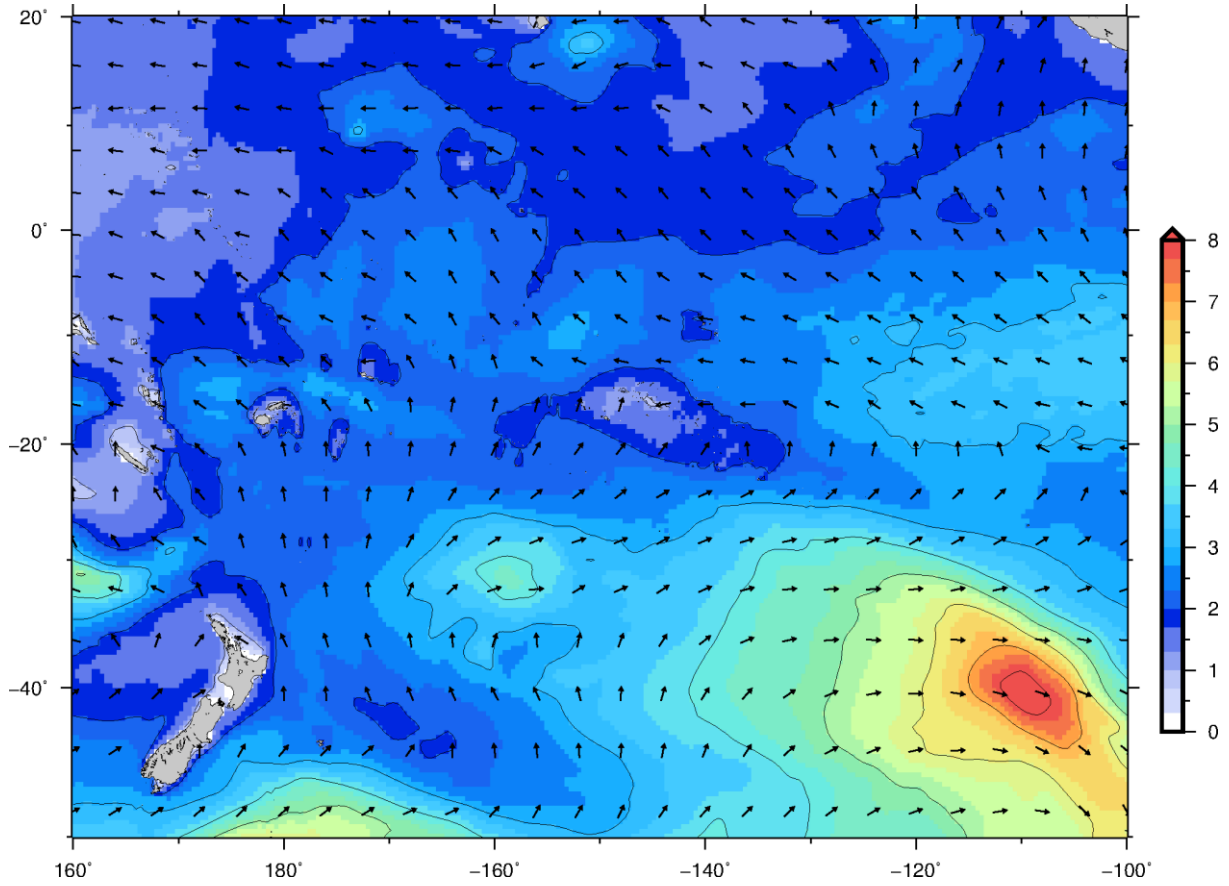

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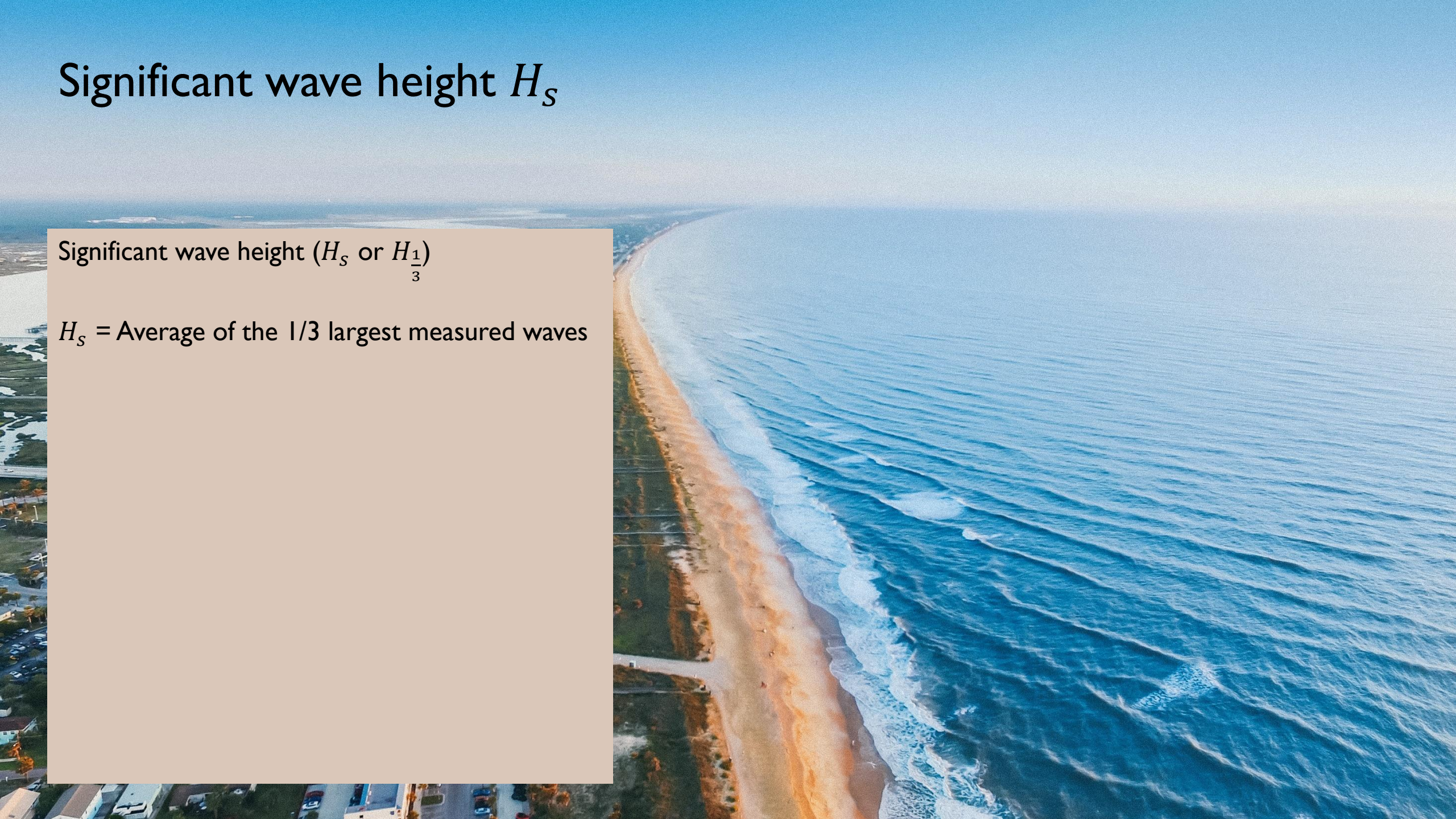

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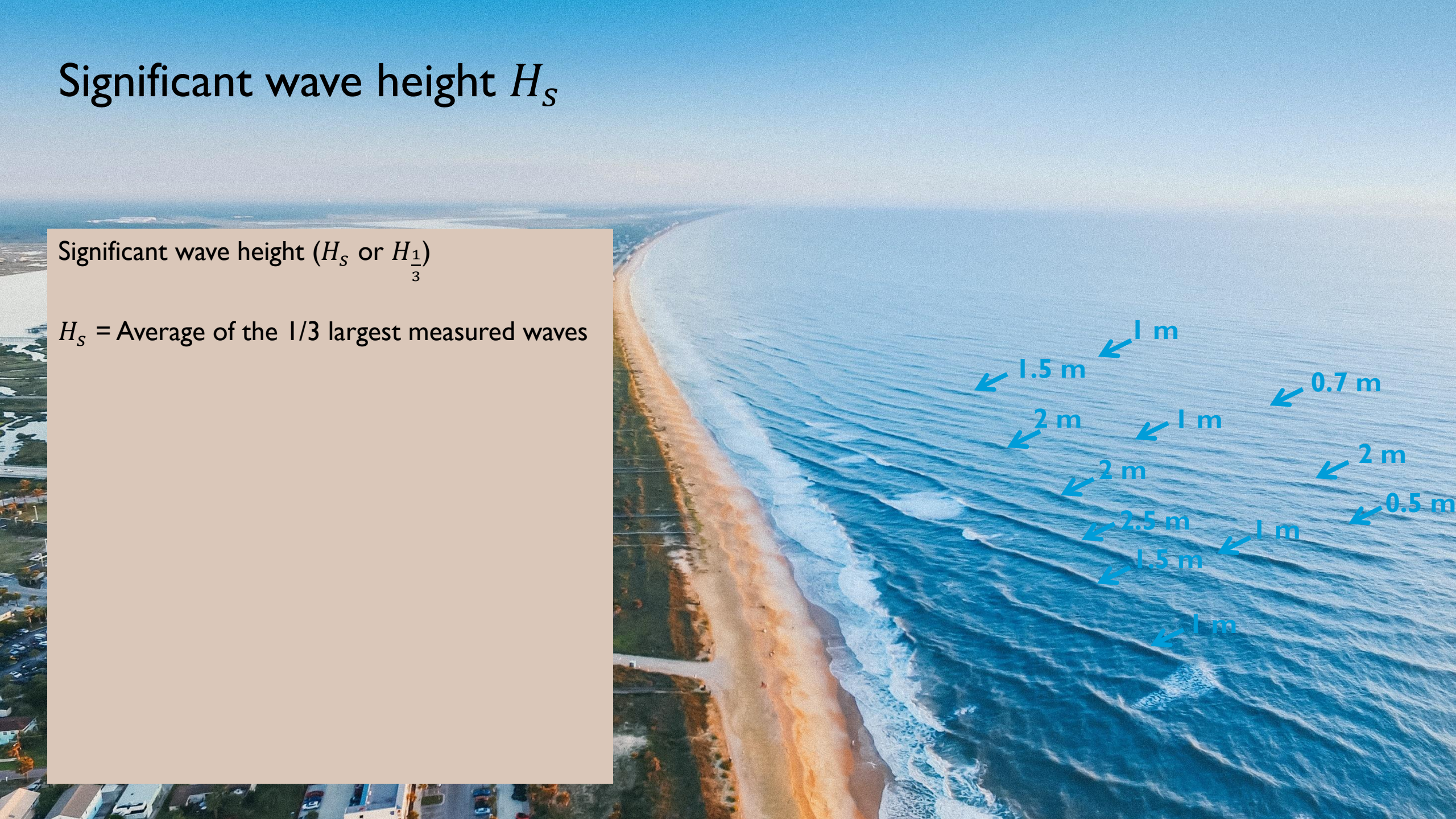

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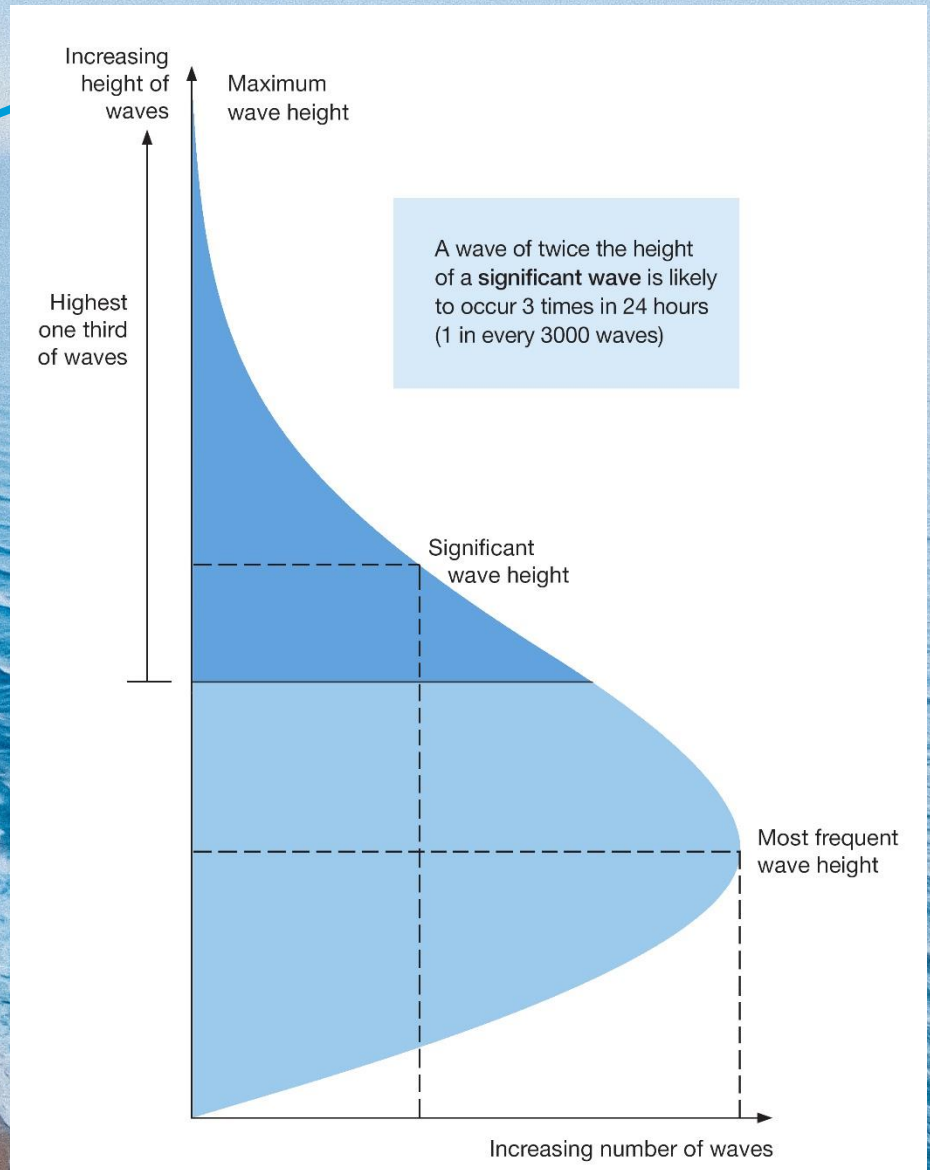
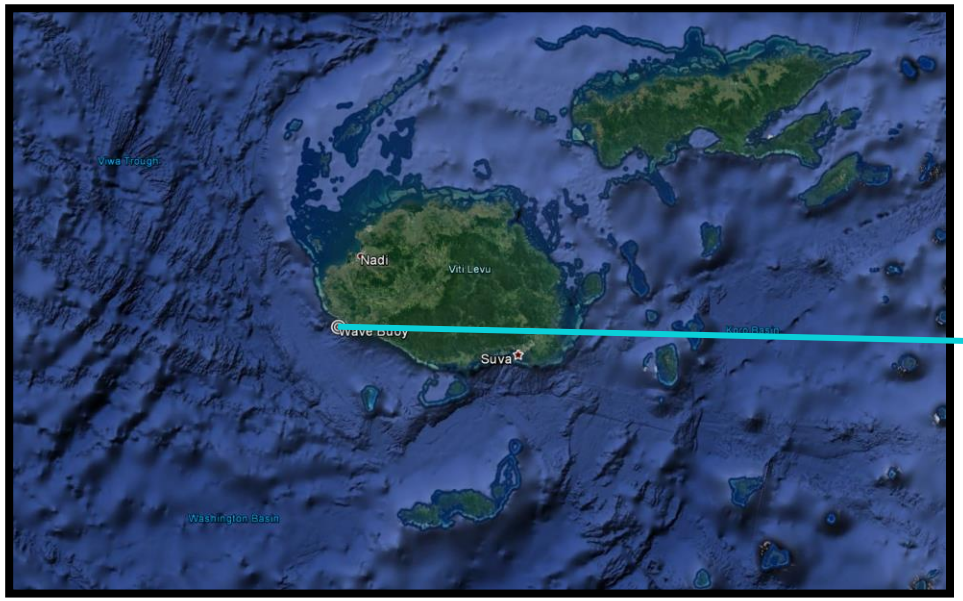
Matches a human's perception of the sea state

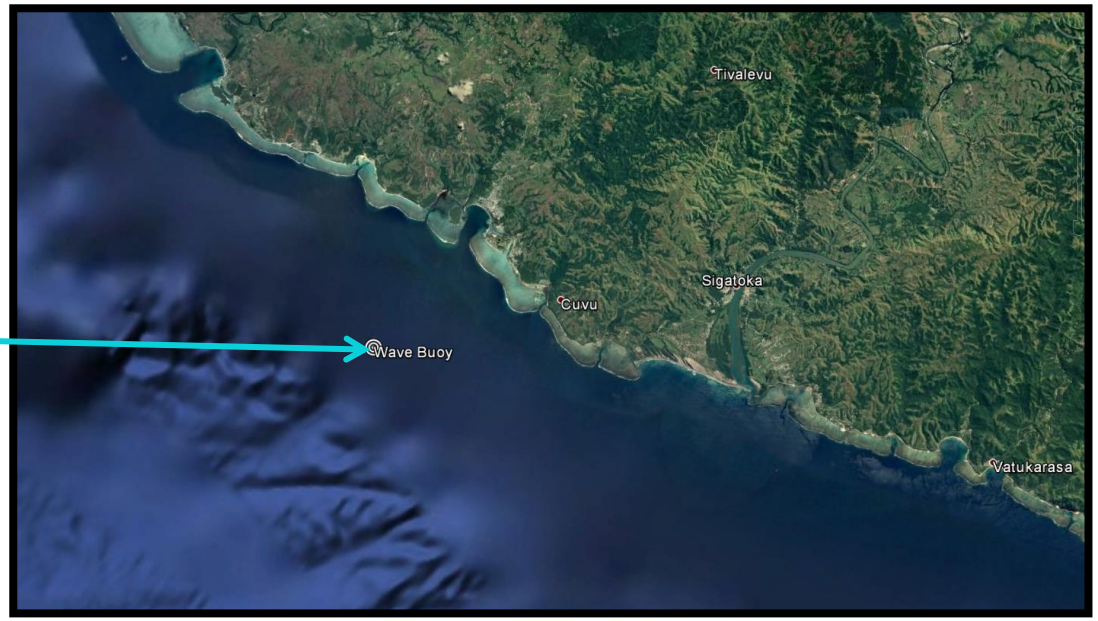
www.bom.gov.au

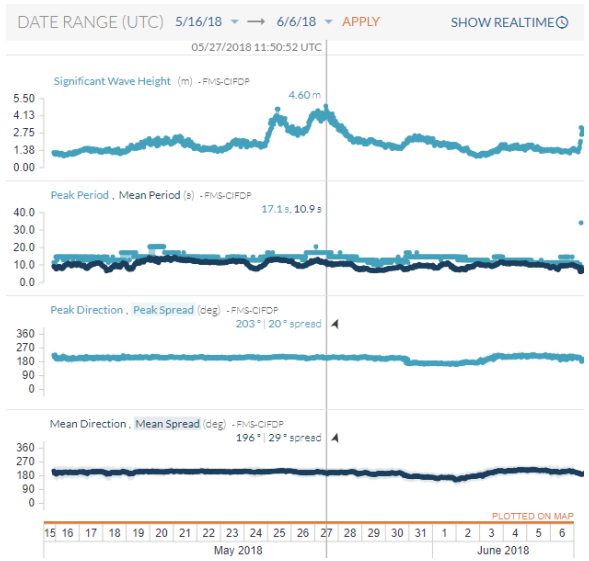


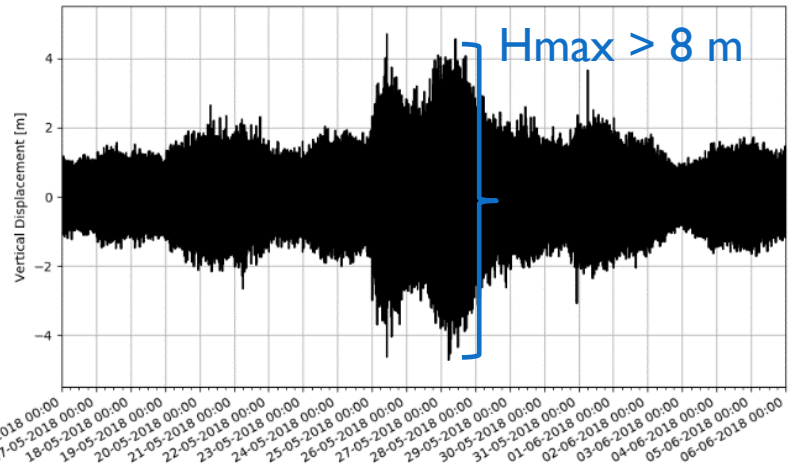
5 m

Case Study: May 2018 Wave event









Beaufort scale (1838)

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Estimating Wind Speed and Sea State with Visual Clues

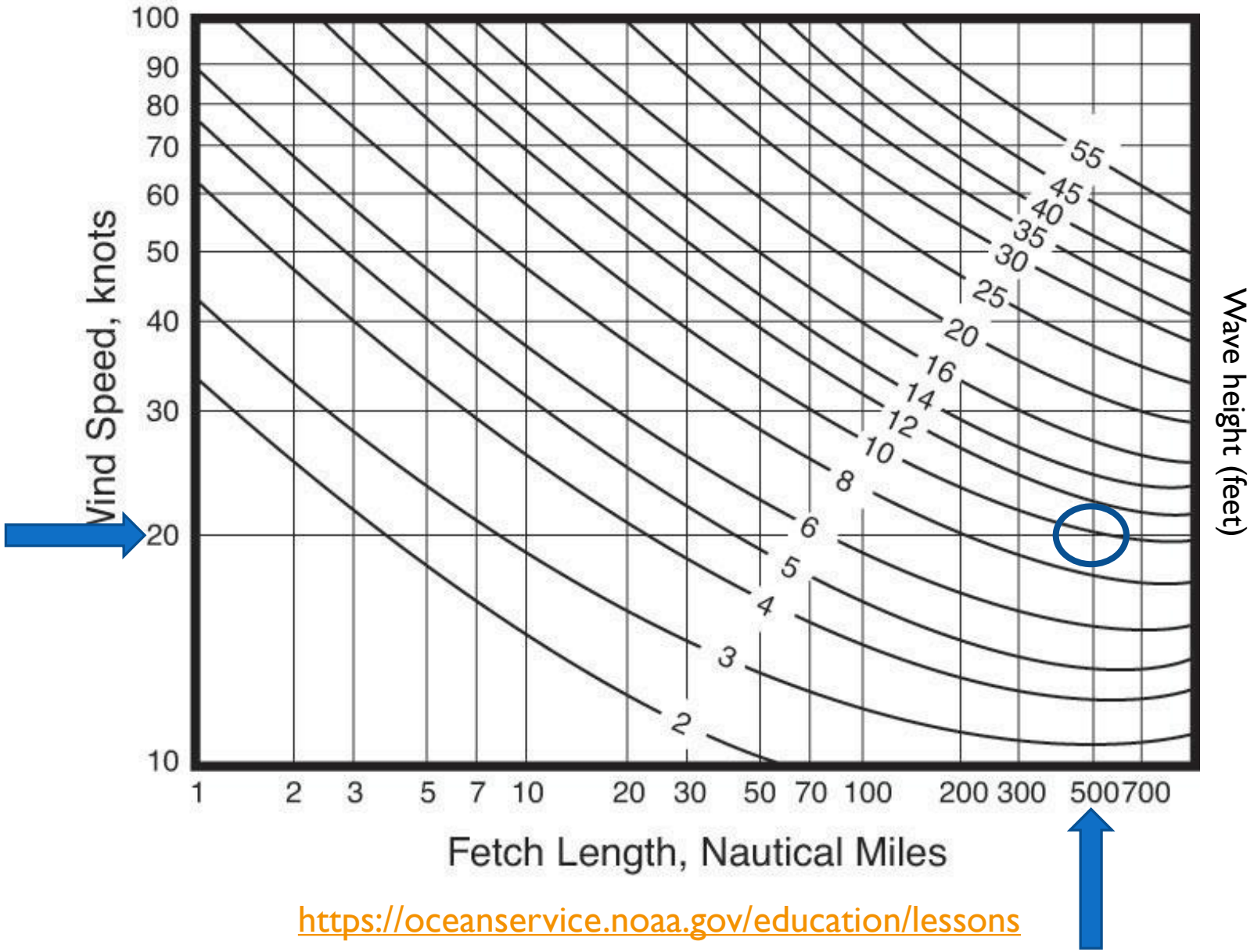
Beaufort number	Wind Description	Wind Speed	Wave Height	Visual Clues
0	Calm	0 knots	0 feet	Sea is like a mirror. Smoke rises vertically.
1	Light Air	1-3 kts	< 1/2	Ripples with the appearance of scales are formed, but without foam crests. Smoke drifts from funnel.
2	Light breeze	4-6 kts	1/2 ft (max 1)	Small wavelets, still short but more pronounced, crests have glassy appearance and do not break. Wind felt on face. Smoke rises at about 80 degrees.
3	Gentle Breeze	7-10 kts	2 ft (max 3)	Large wavelets, crests begin to break. Foam of glassy appearance. Perhaps scattered white horses (white caps). Wind extends light flag and pennants. Smoke rises at about 70 deg.
4	Moderate Breeze	11-16 kts	3 ft (max 5)	Small waves, becoming longer. Fairly frequent white horses (white caps). Wind raises dust and loose paper on deck. Smoke rises at about 50 deg. No noticeable sound in the rigging. Slack halyards curve and sway. Heavy flag flaps limply.
5	Fresh Breeze	17-21kts	6 ft (max 8)	Moderate waves, taking more pronounced long form. Many white horses (white caps) are formed (chance of some spray). Wind felt strongly on face. Smoke rises at about 30 deg. Slack halyards whip while bending continuously to leeward. Taut halyards maintain slightly bent position. Low whistle in the rigging. Heavy flag doesn't extended but flaps over entire length.
6	Strong Breeze	22-27 kts	9 ft (max 12)	Large waves begin to form. White foam crests are more extensive everywhere (probably some spray). Wind stings face in temperatures below 35 deg F (2C). Slight effort in maintaining balance against wind. Smoke rises at about 15 deg. Both slack and taut halyards whip slightly in bent position. Low moaning, rather than whistle, in the rigging. Heavy flag extends and flaps more vigorously.
7	Near Gale	28-33 kts	13 ft (max 19)	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of wind. Necessary to lean slightly into the wind to maintain balance. Smoke rises at about 5 to 10 deg. Higher pitched moaning and whistling heard from rigging. Halyards still whip slightly. Heavy flag extends fully and flaps only at the end. Oilskins and loose clothing inflate and pull against the body.
8	Gale	34-40 kts	18 ft (max 25)	Moderately high waves of greater length. Edges of crests begin to break into the spindrift. The foam is blown in well-marked streaks along the direction of the wind. Head pushed back by the force of the wind if allowed to relax. Oilskins and loose clothing inflate and pull strongly. Halyards rigidly bent. Loud whistle from rigging. Heavy flag straight out and whipping.
9	Strong Gale	41-47 kts	23 ft (max 32)	High waves. Dense streaks of foam along direction of wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.
10	Storm	48-55 kts	29 ft (max 41)	Very high waves with long overhanging crests. The resulting foam, in great patches is blown in dense streaks along the direction of the wind. On the whole, the sea takes on a whitish appearance. Tumbling of the sea becomes heavy and shock-like. Visibility affected.
11	Violent Storm	56-63 kts	37 ft (max 52)	Exceptionally high waves (small and medium-sized ships might be for time lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere, the edges of the wave crests are blown into froth. Visibility greatly affected.
12	Hurricane	64+ kts	45+ ft	The air is filled with foam and spray. The sea is completely white with driving spray. Visibility is seriously affected.

Example:

What is the wave height if the wind speed is 20 knots?

www.weather.gov/pqr/beaufort

Sverdrup-Munk-Bretschneider Nomogram (1952)



https://oceanservice.noaa.gov/education/lessons

Example:

What is the wave height if the wind speed is 20 knots and the wind fetch is 500 nmi?

Manual Wave Forecasting Diagram

(Gröen and Dorrestein, 1976)

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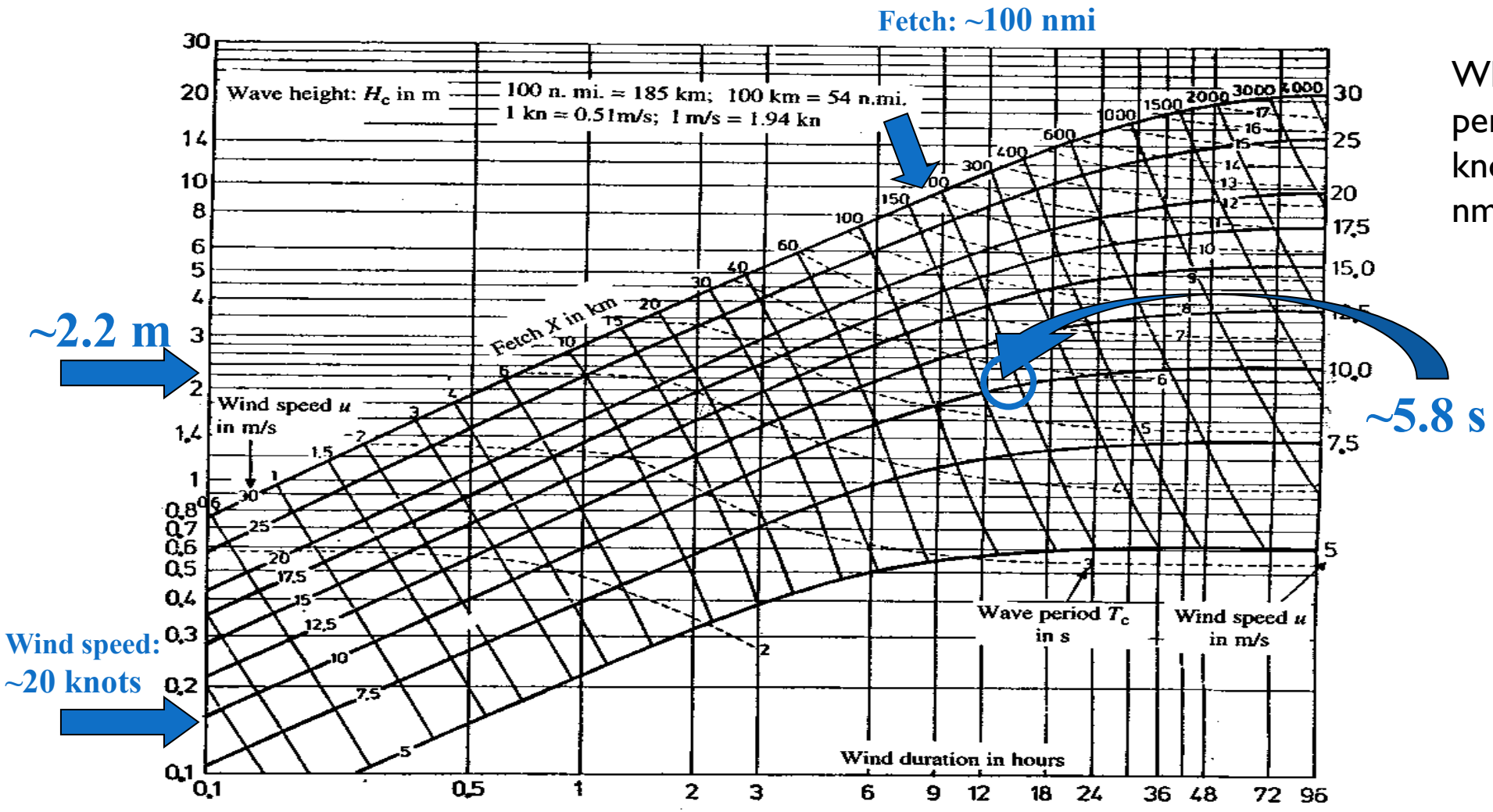


Figure 4.1 — Manual wave forecasting diagram (*from Gröen and Dorrestein, 1976*)

Example:

What is the wave height and period if the wind speed is 20 knots and the wind fetch is 100 nmi?

Excercise

Predict the wave heights (and if possible wave periods) in Fiji for tomorrow 12 pm, using Windy.com and the following tool:

a) the Beaufort Scale

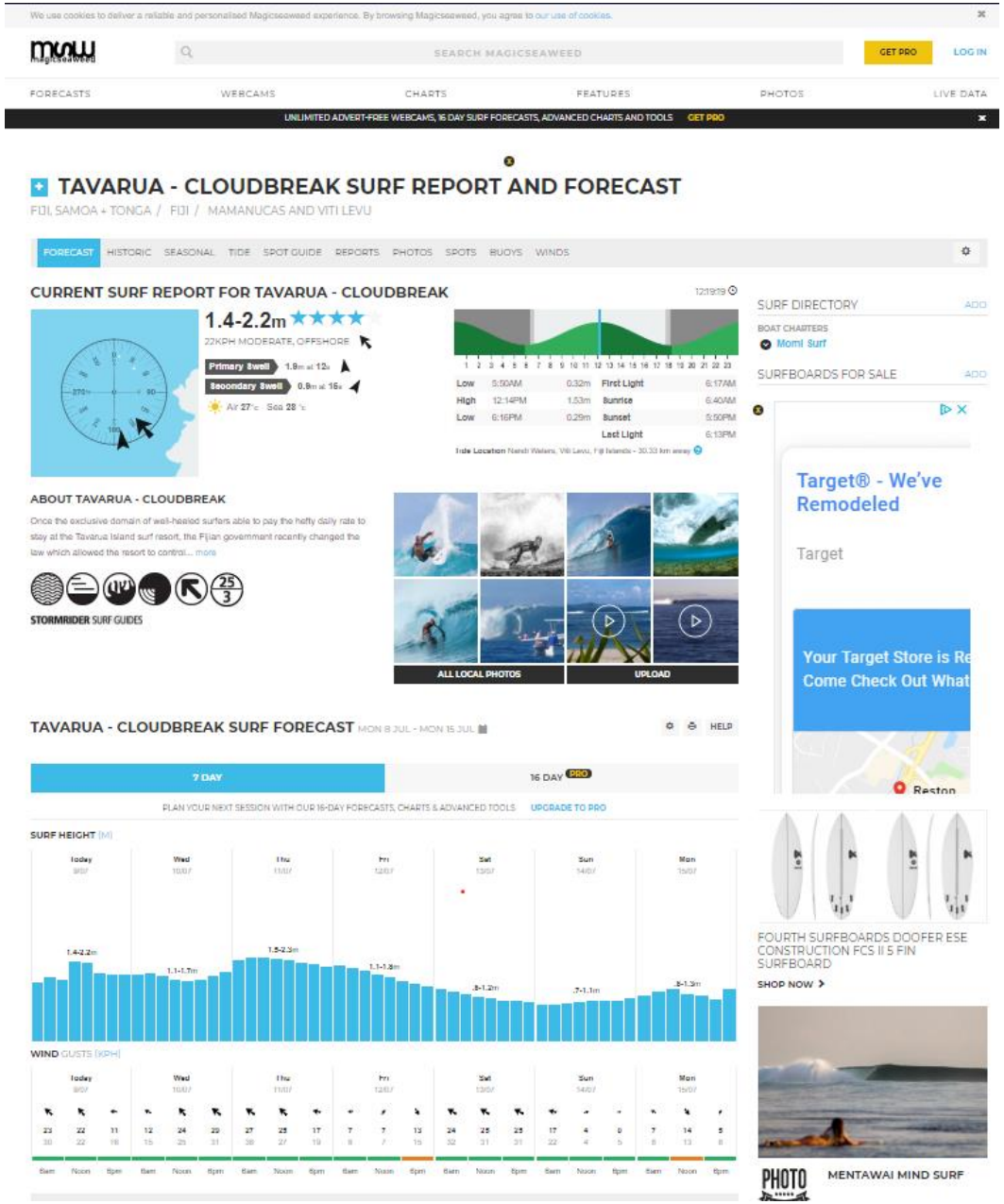
b) the Sverdrup-Munk-Bretschneider Nomogram

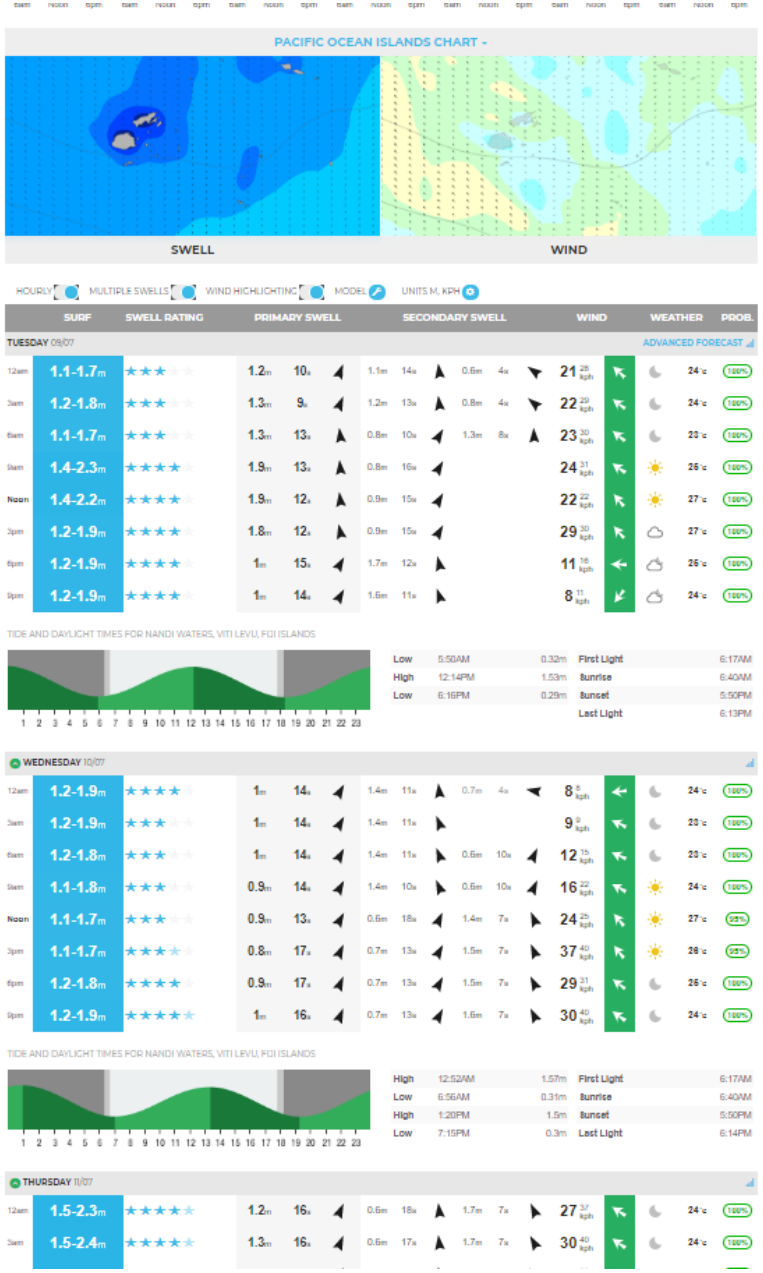
c) the manual wave forecasting diagram

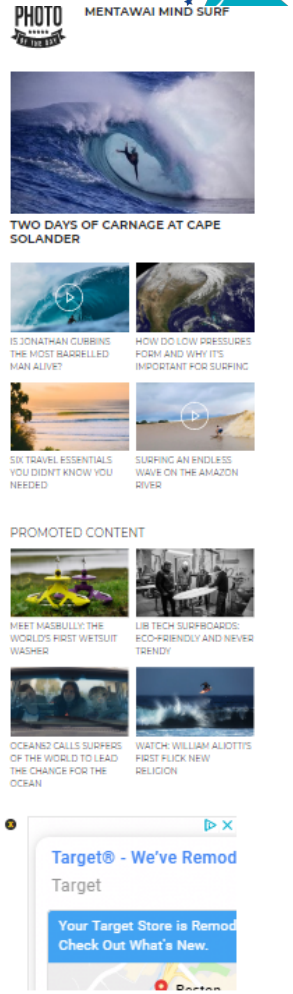
Hint: You can use windy.com and the distance tool.

How do your predictions differ from the windy.com wave forecast?

MAGICSEAWEED.COM







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WINDGURU.CZ

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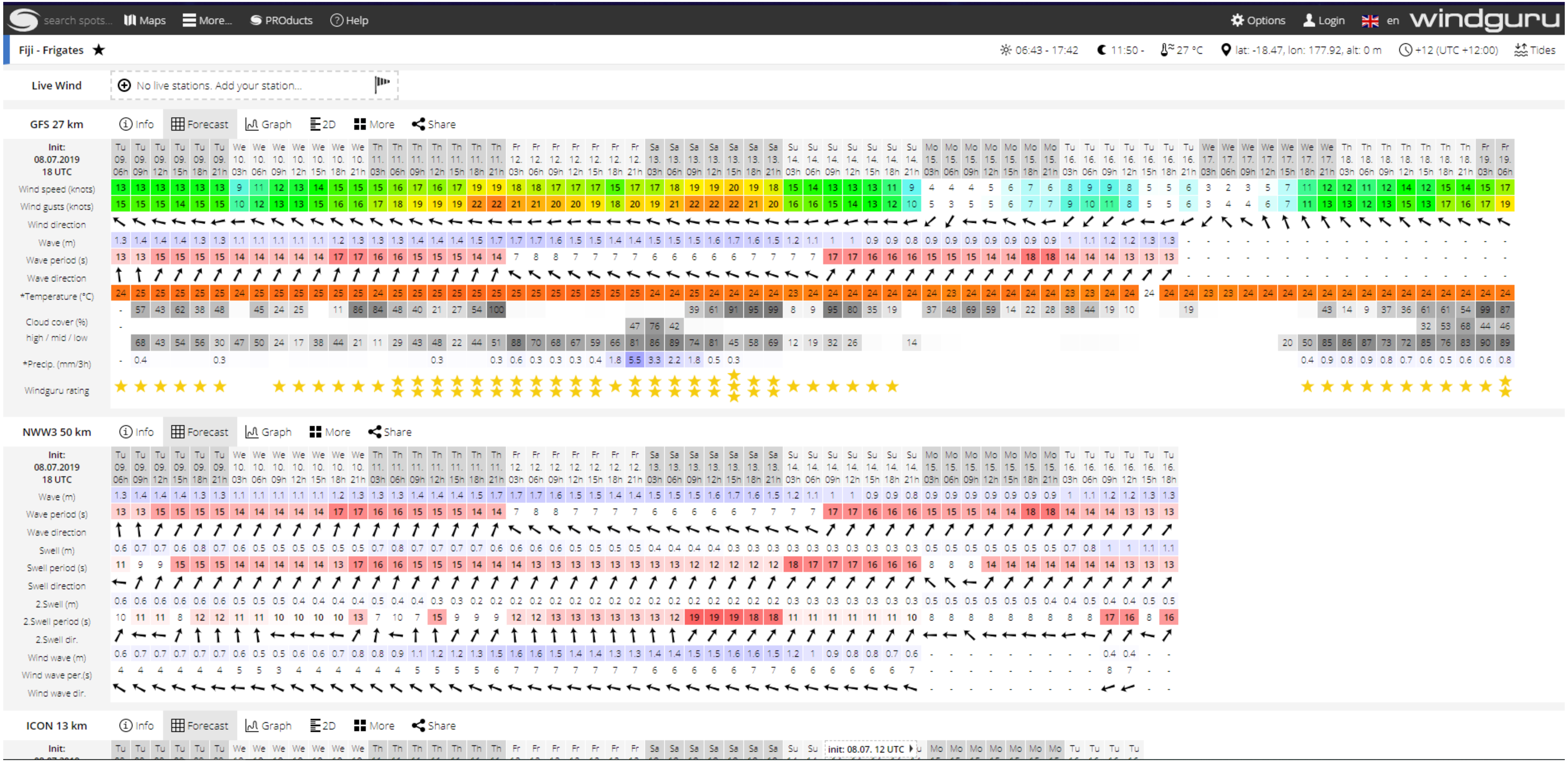

WINDY.COM

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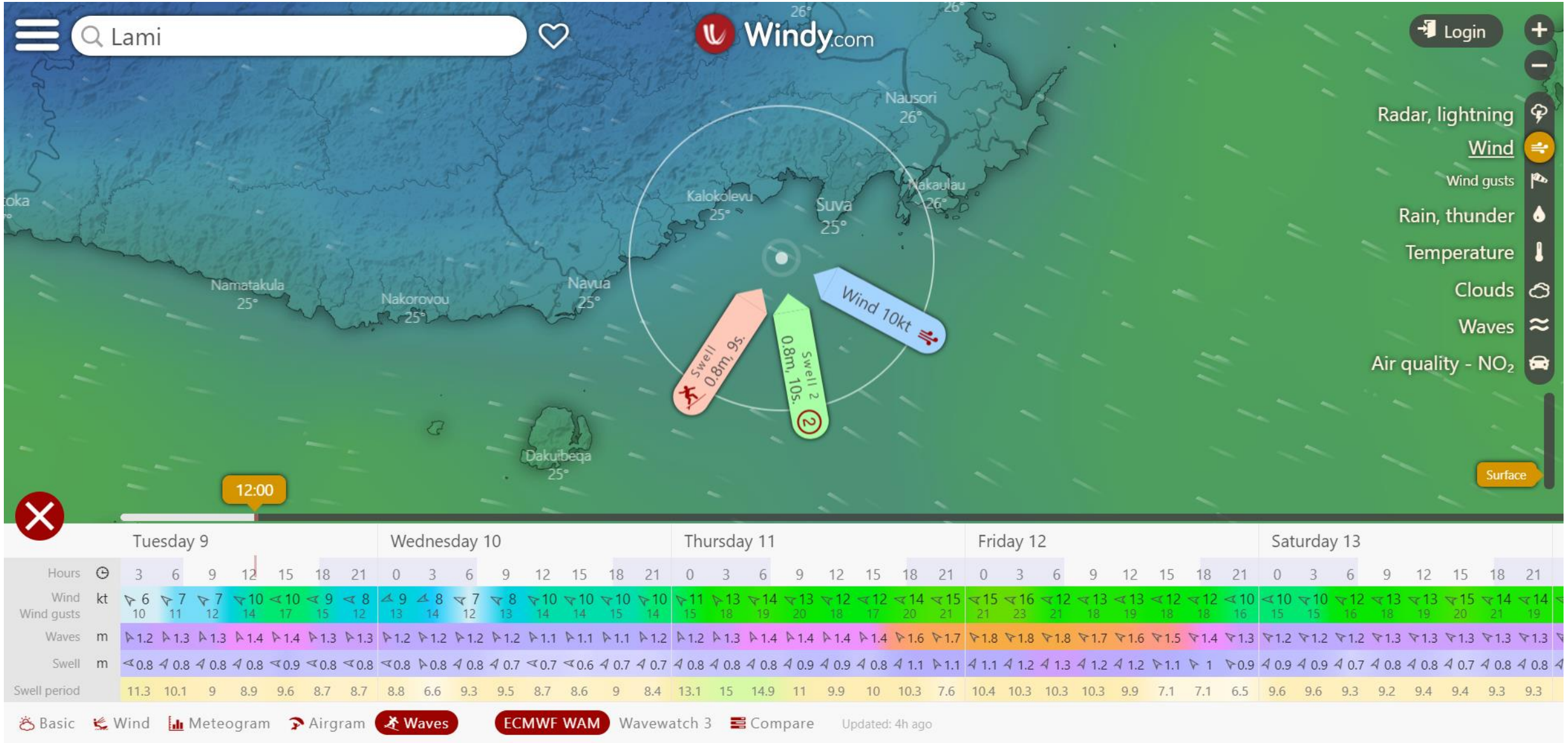
Communauté du Pacifique



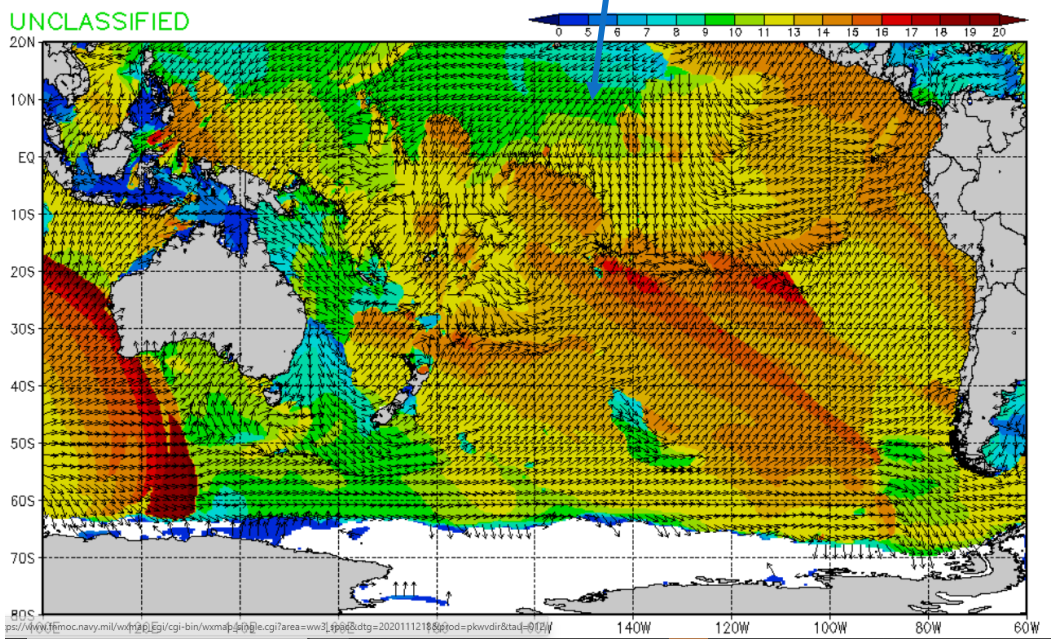
Naval Oceanography Portal

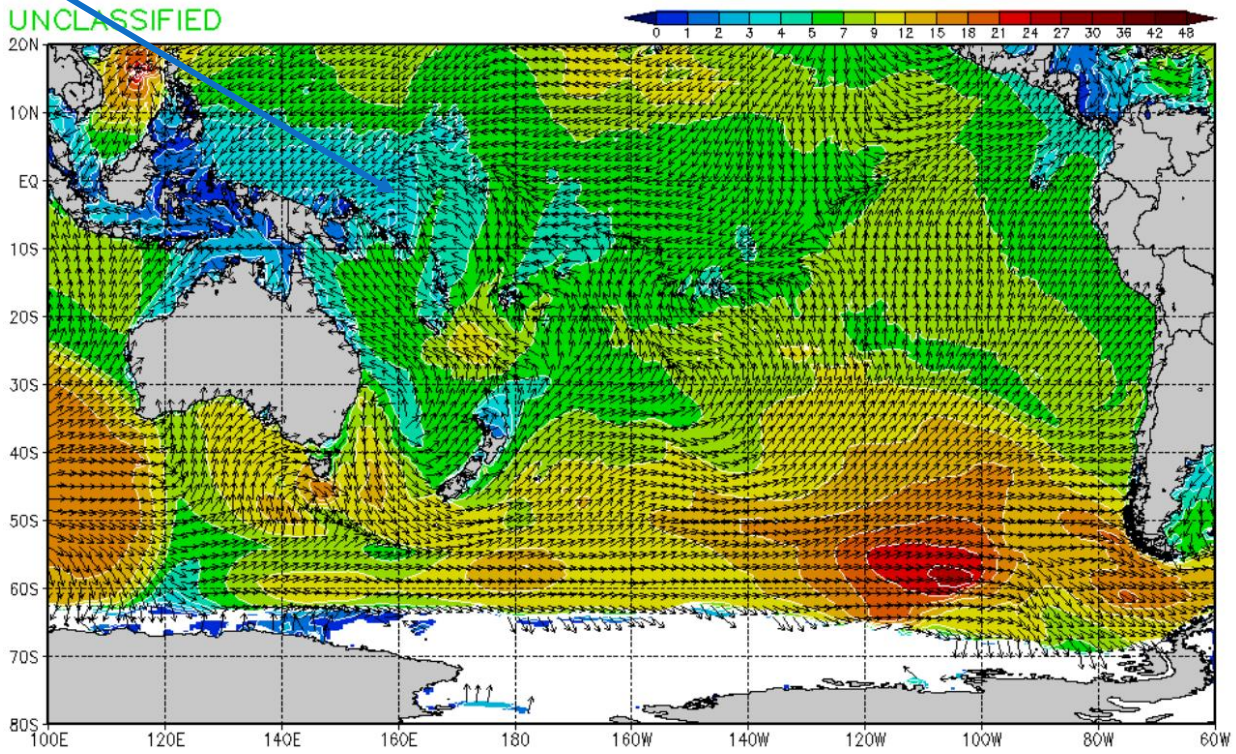
Pacific Community
Communauté du Pacifique

FNMOC

https://www.usno.navy.mil/FNMOC

- Significant Wave Height & Direction (based on Official TC Warning)
- Significant Wave Height & Direction
- Swell Wave Height & Direction
- Wind Wave Height & Direction
- Swell Wave Period & Direction
- Wind Wave Period & Direction
- Peak Wave Period & Direction
- White Cap Probability
- Sea Surface Temperature





SURF-FORECAST.COM

Pacific Community
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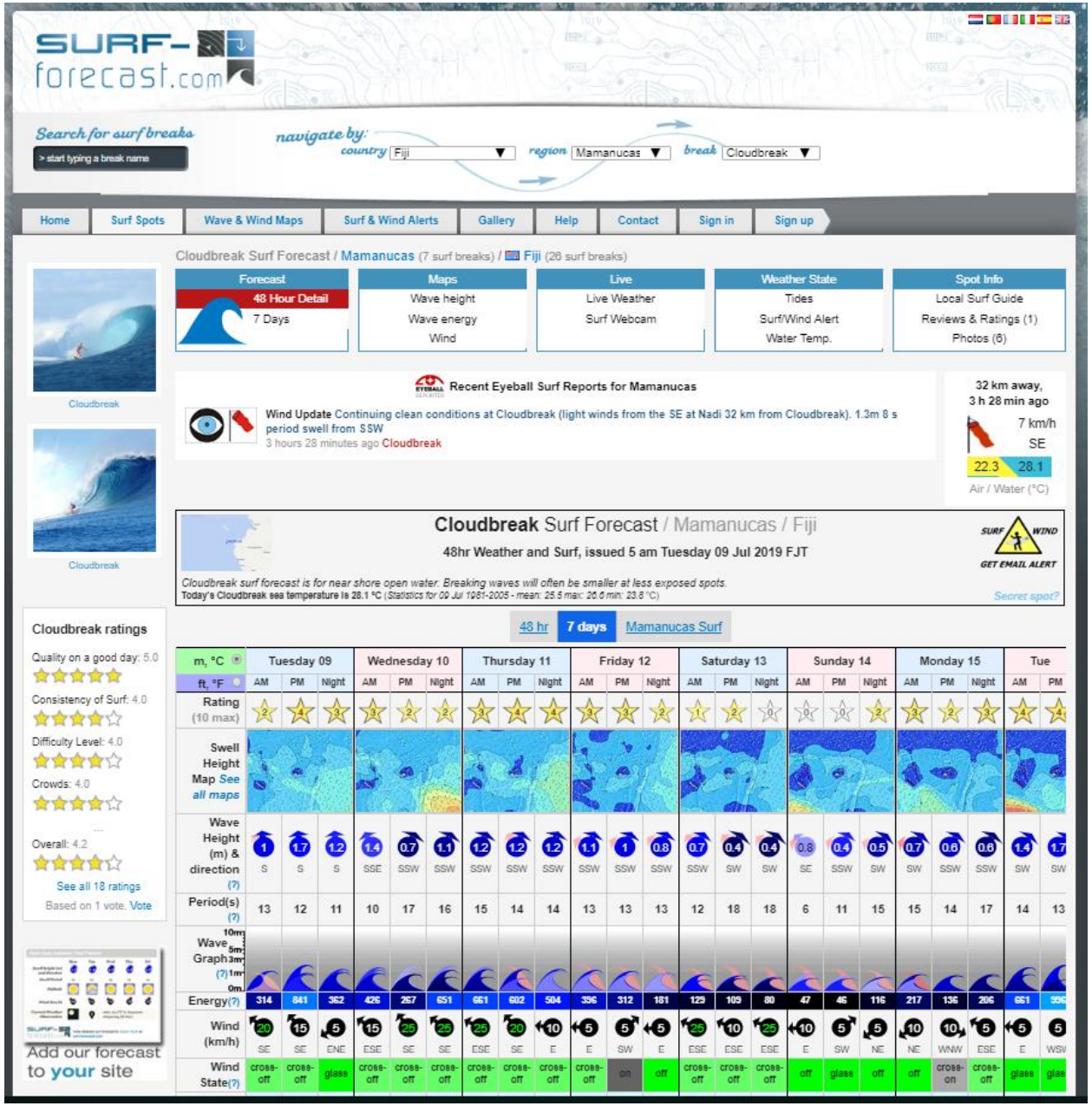
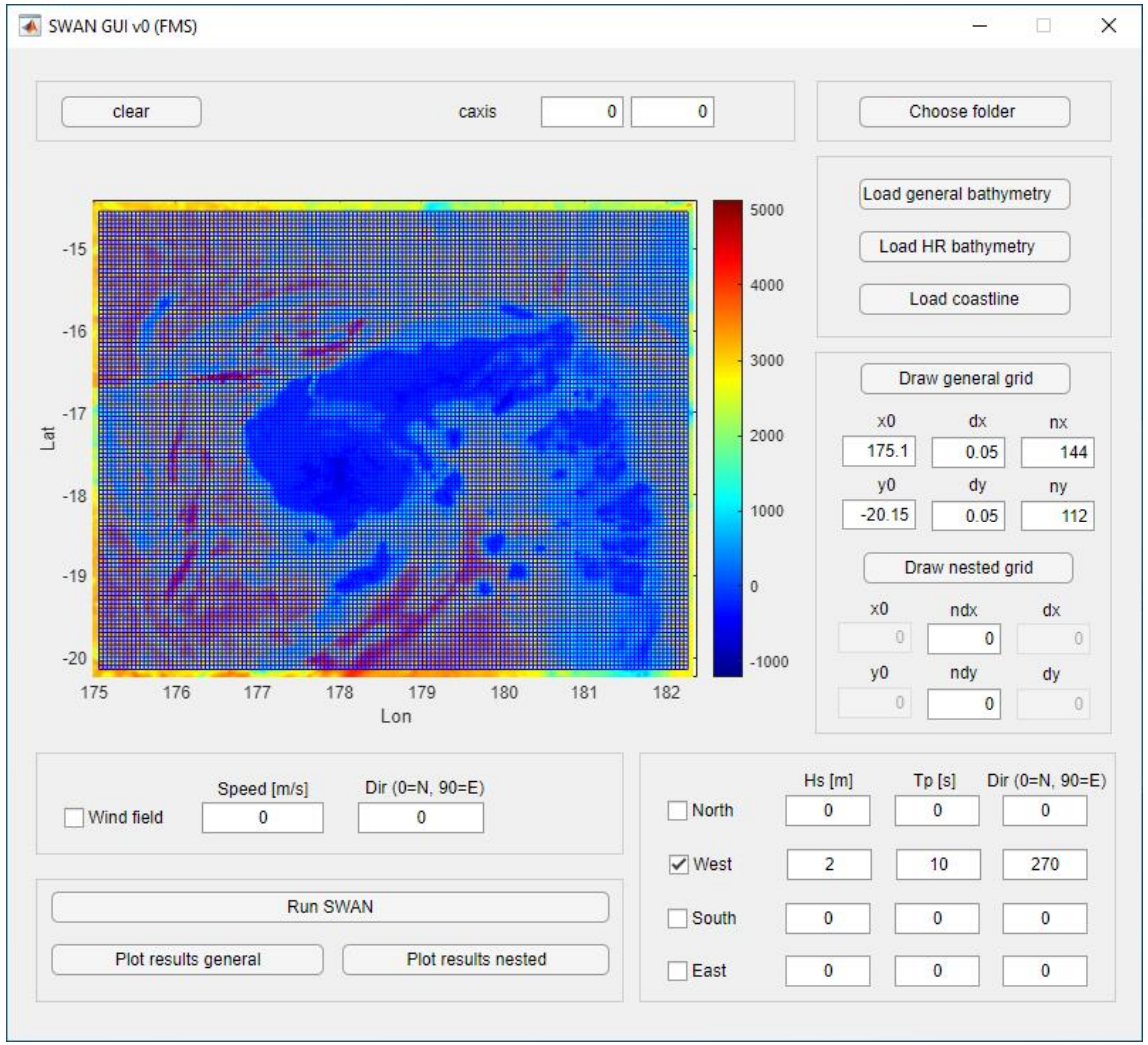


ADVANCED SWAN MODELLING

OVERVIEW

So far we have used a friendly easy to use GUI to set up basic SWAN model configuration

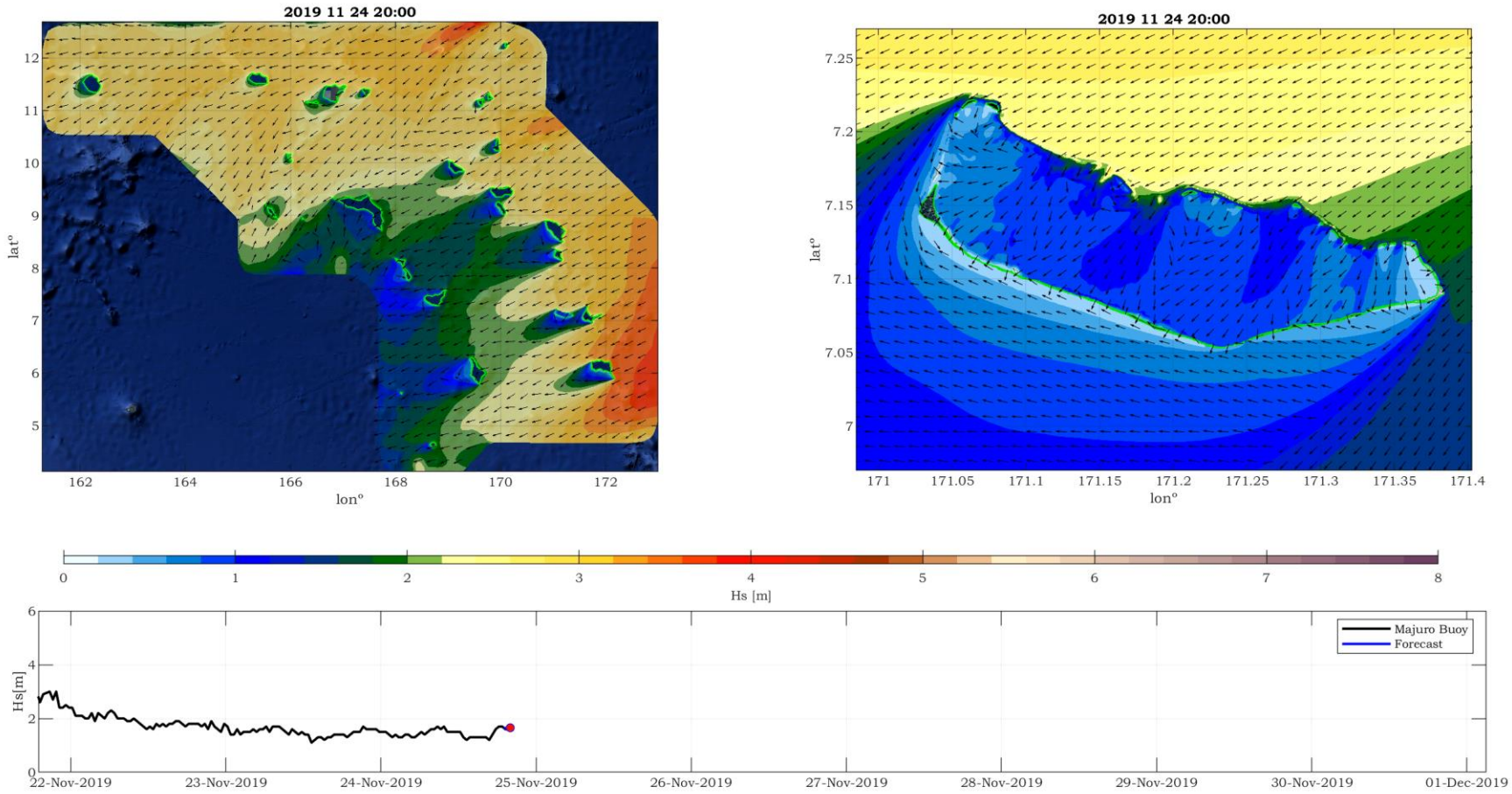
- We have run stationary scenarios.
  - Shouldn't be applied to big domains, when the dimension of the domain is so big that waves take more than 30 min to 1 hour to travel from the boundaries to our target area is (i.e. <<50-100 Km)
  - When waves and winds are changing quickly.
- Wave boundaries have been defined by means of bulk parameters
  - Not valid when we have more than 1 wave system *(i.e. south swell + wind waves)
  - Critical to model wave inundation
- Wind conditions are spatially constant
  - Not applicable to big domains where winds changes substantially
  - Tropical cyclones



A general suggestion is: start simple. SWAN helps in this with default options. Furthermore, suggestions are given that should help the user to choose among the many options conditions and in which mode to run SWAN (first-, second- or third-generation mode, stationary or nonstationary and 1D or 2D).

STATIONARY vs. NONSTATIONARY

- Stationary runs are used to analyse how certain wave conditions will propagate under a given bathymetry (engineering applications)
- For wave forecast, non-stationary is more convenient as we are interested in resolving large domains with no steady boundary conditions



BULK PARAMETERS vs. WAVE SPECTRA

How you would define the waves approaching to the coast in this image?

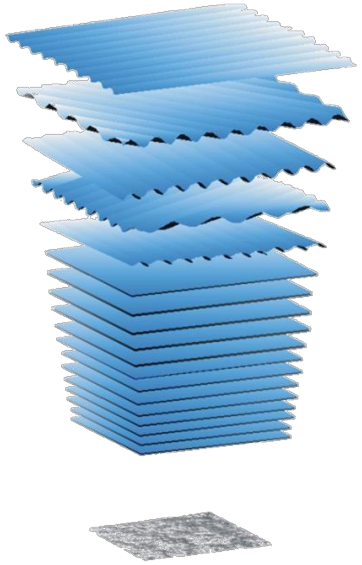
Hs_1, Tp_1, Dir_1

Hs_2, Tp_2, Dir_2

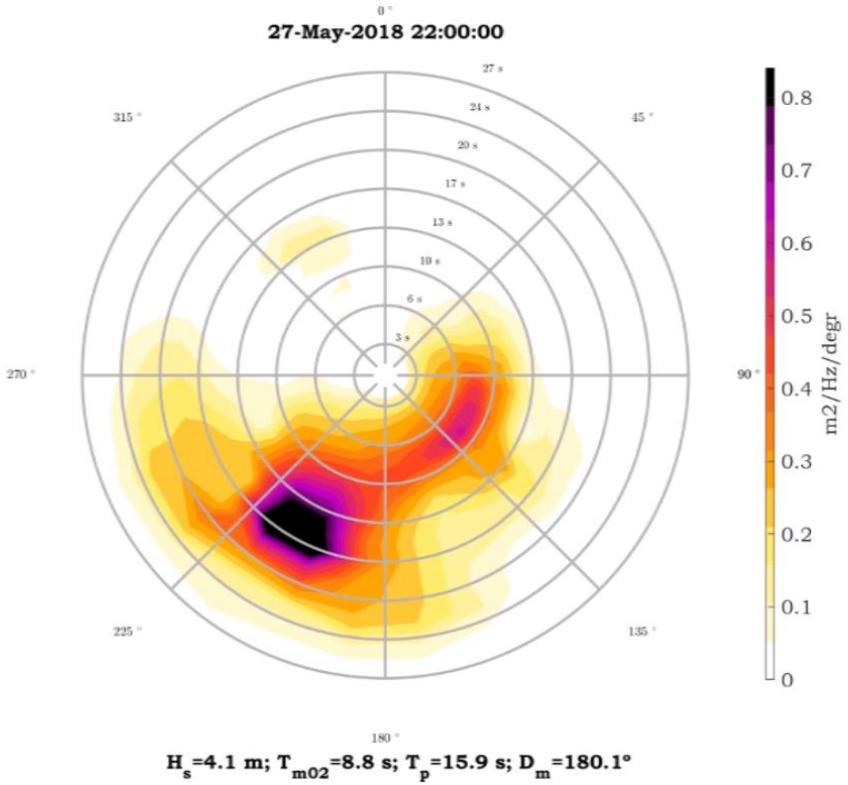
$$\eta(x, y, t) = \sum_j a_j \cos\left\{\frac{\omega_j^2}{g}\left(x\cos\theta_j + y sen\theta_j\right) - \omega_j t + \varepsilon_j\left(\omega_j, \theta_j\right)\right\}$$

BULK PARAMETERS vs. WAVE SPECTRA

- The sea surface at any time can be approximated to a summation of a number of waves trains coming from different wave periods and directions
- The wave spectra tell us how the wave energy is distributed on the frequency (wave periods) and direction domain.

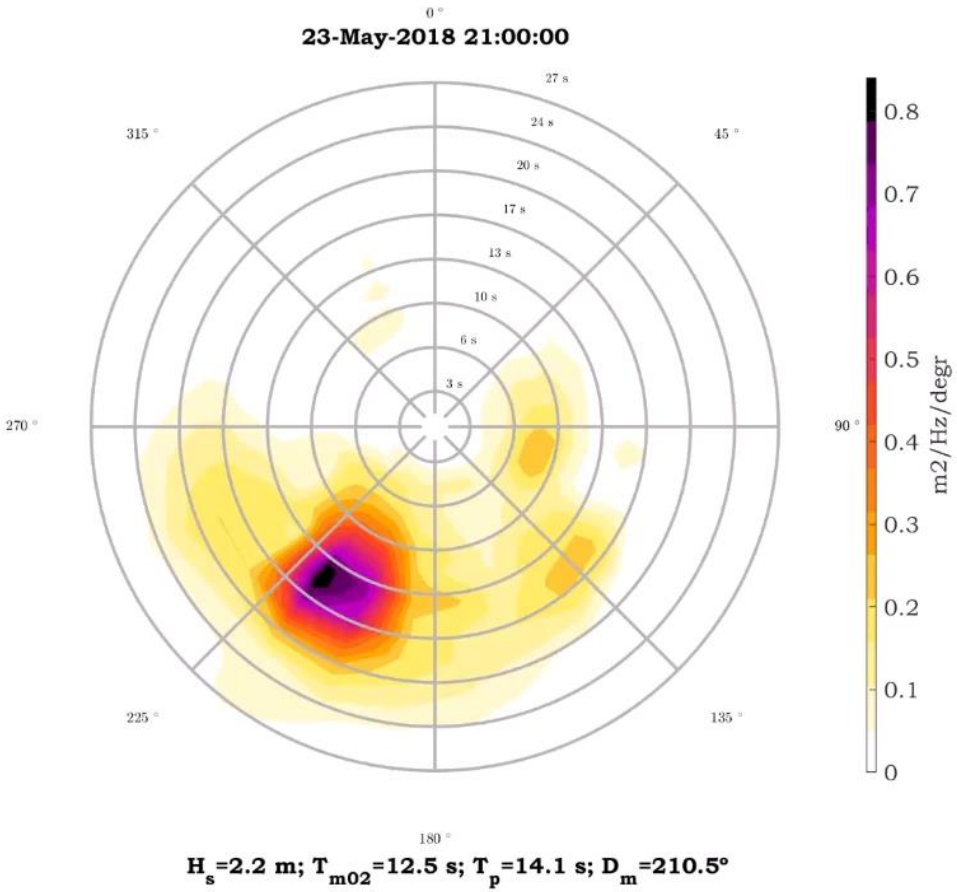


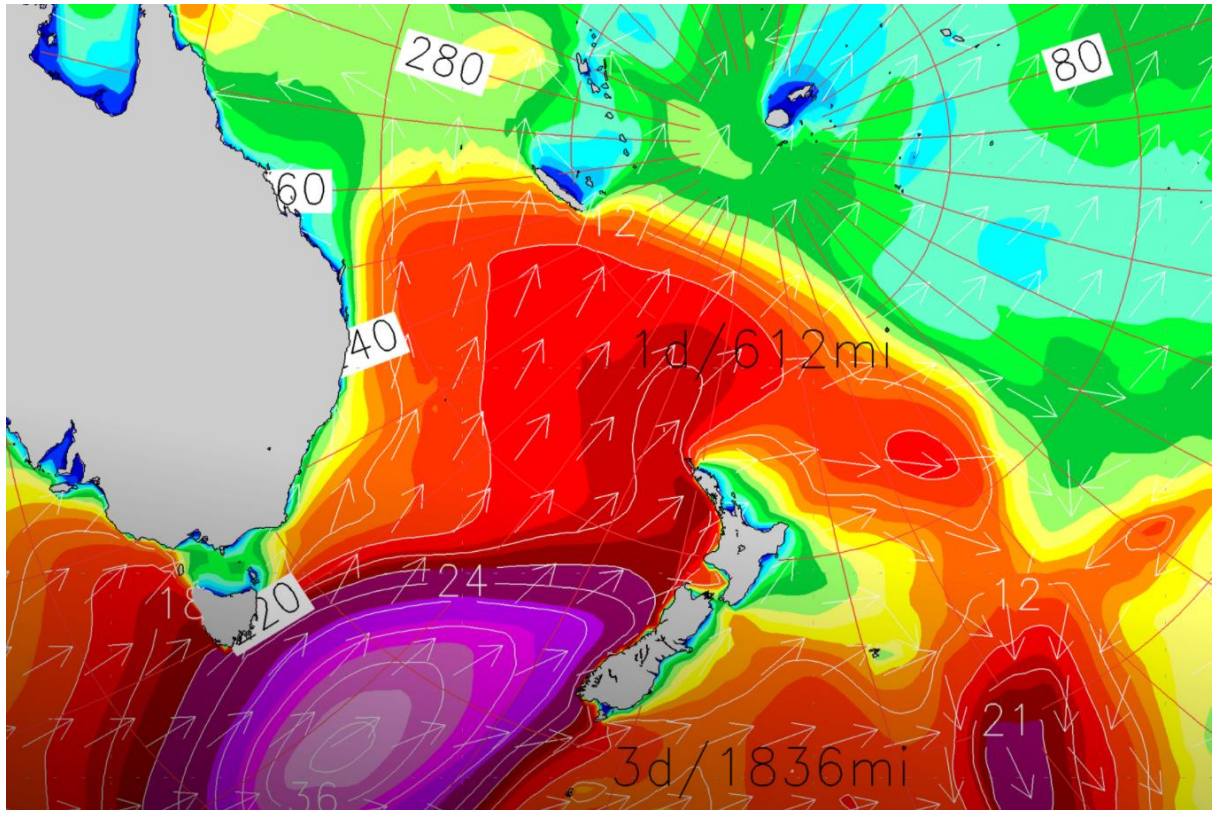
$$\eta(x,\ y,\ t) = \sum_j a_j \cos\left\{\frac{\omega_j^2}{g}\left(x\cos\theta_j + y sen\theta_j\right) - \omega_j t + \varepsilon_j\left(\omega_j, \theta_j\right)\right\}$$



BULK PARAMETERS vs. WAVE SPECTRA

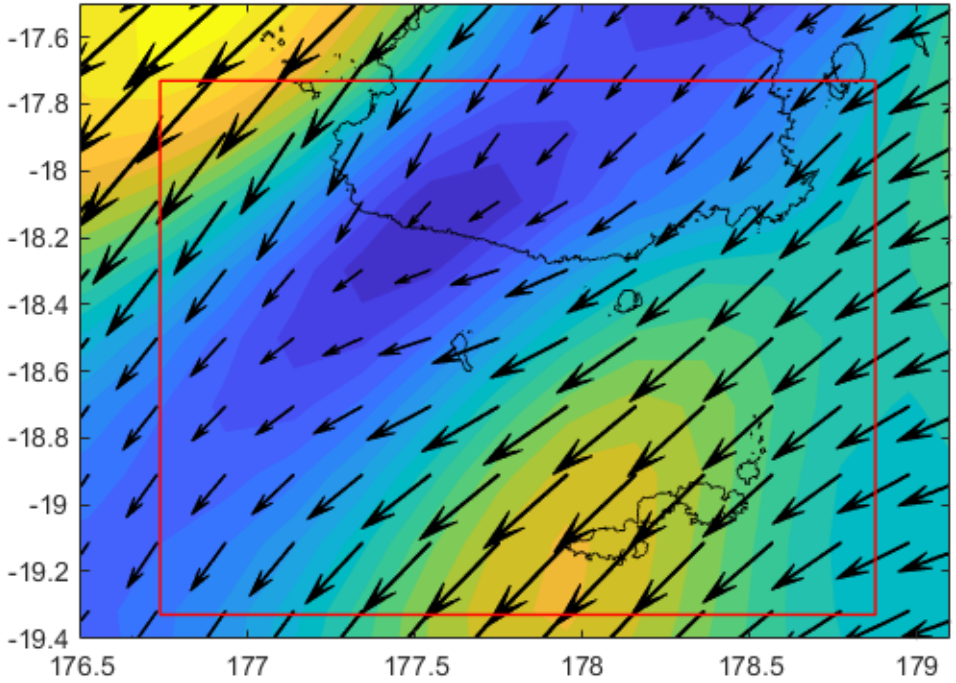
- The wave spectrum can tell us a lot of what is happening around (in term of atmospheric conditions)

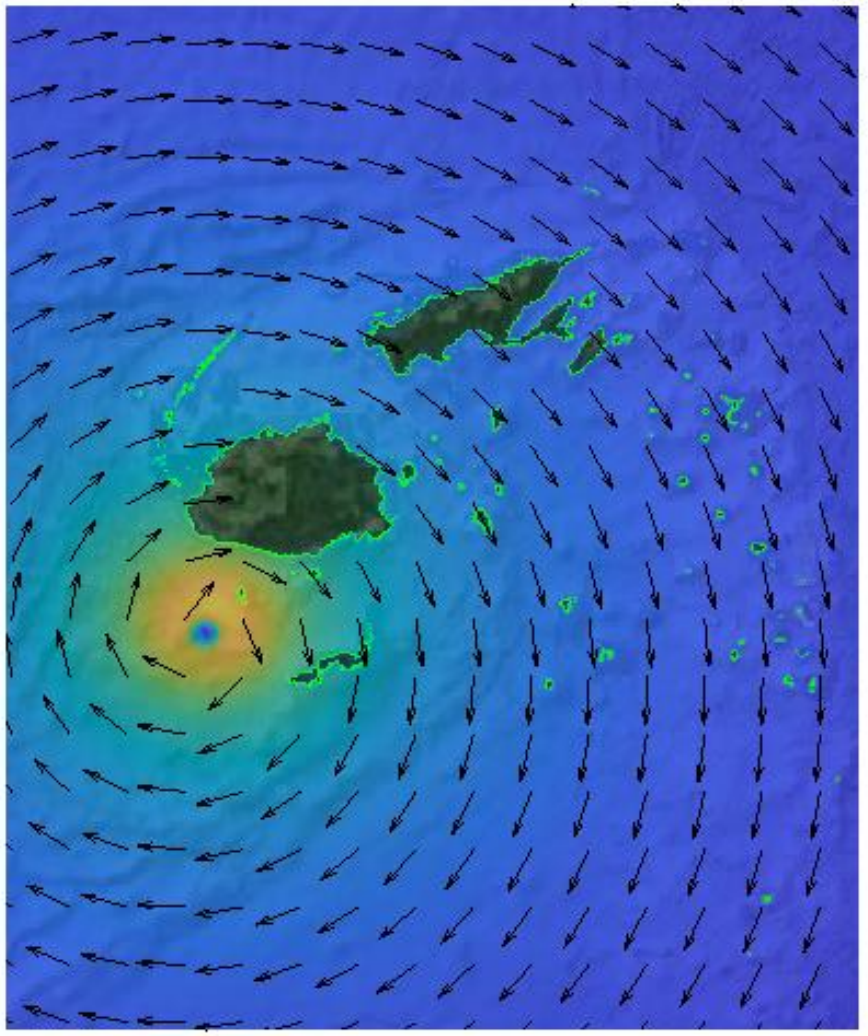




VARIABLE WIND CONDITIONS

- Examples of highly variable winds





HANDS ON, MODELLING CYCLONE HAROLD WAVES IN FIJI

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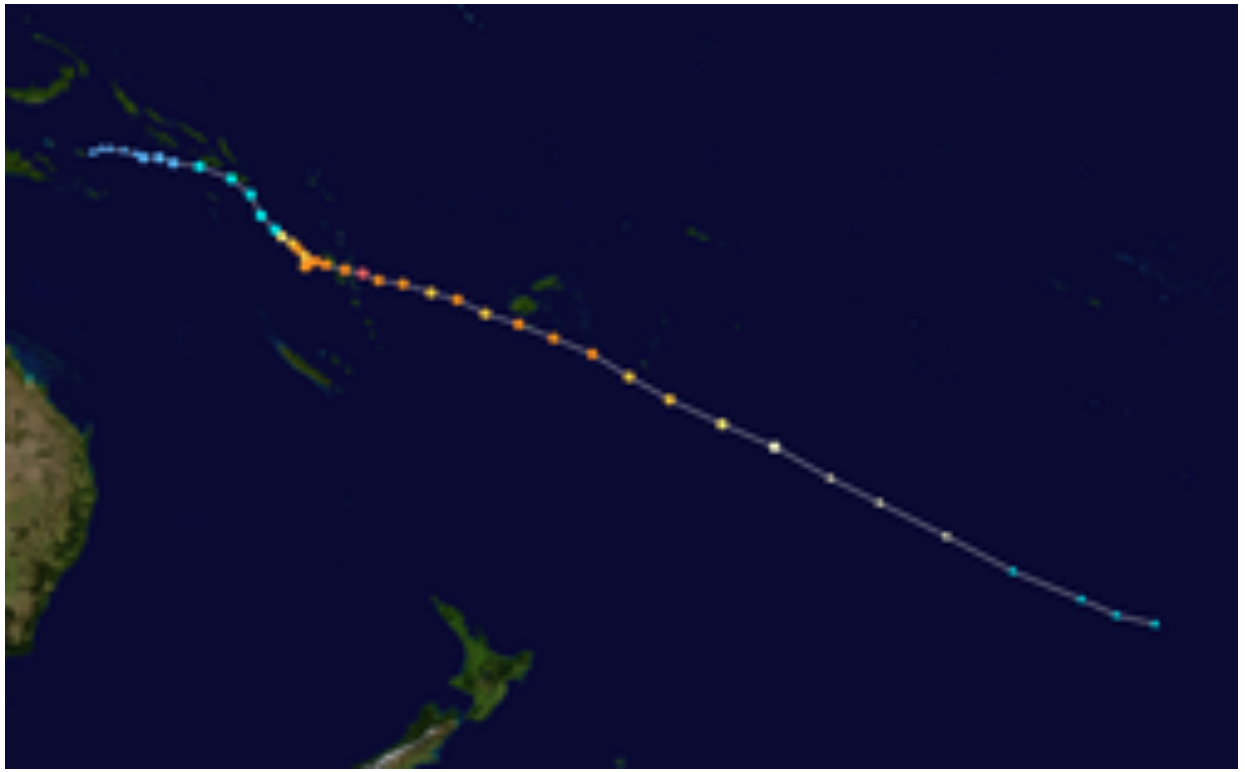
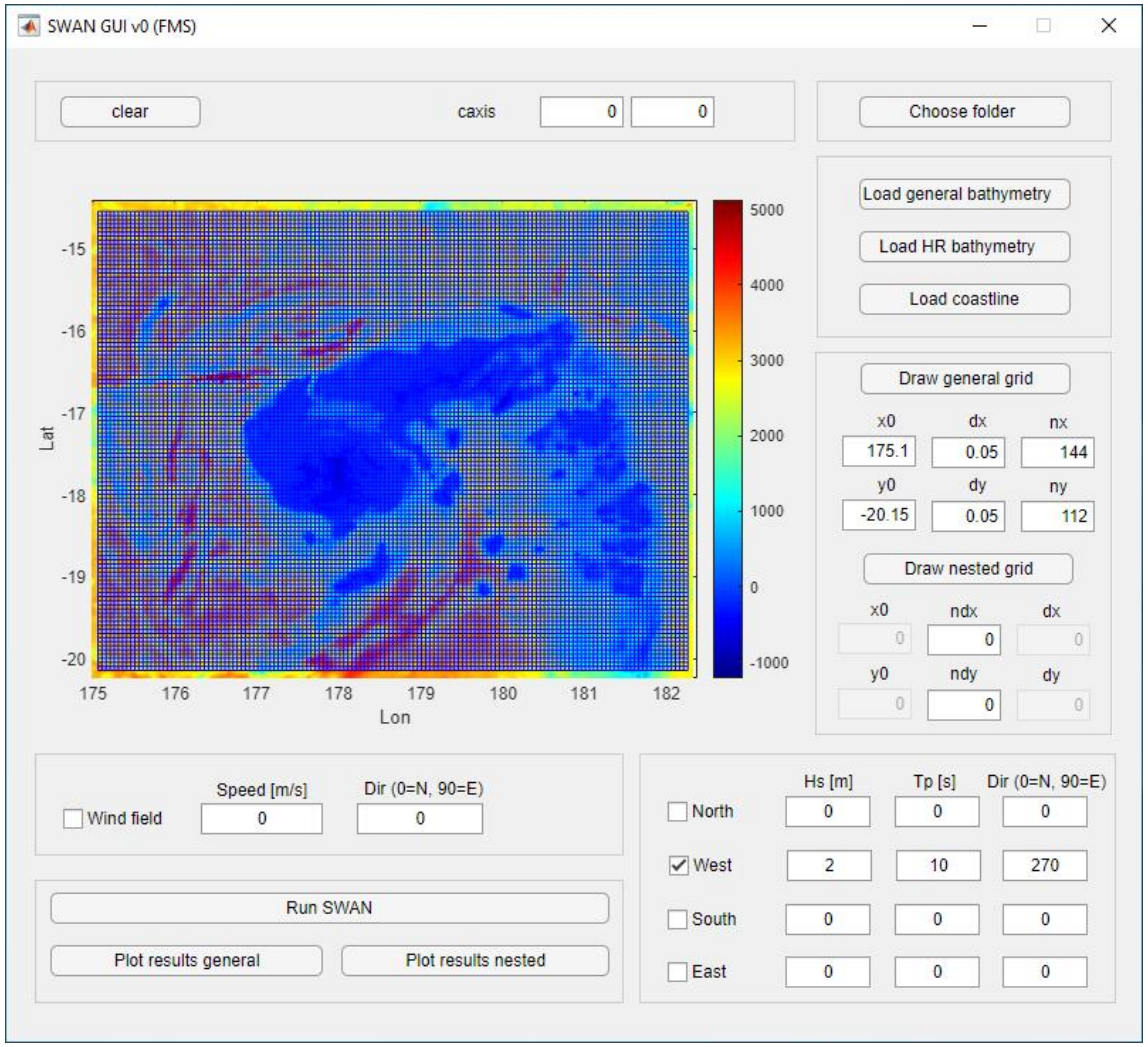


HANDS ON, MODELLING CYCLONE HAROLD WAVES IN FIJI

1. Generate a folder inside runs named Harold
2. Load Gebco_2020_Fiji_500m.xyz in the SWAN_GUI
3. Draw a grid covering as much as possible
4. Define a resolution of 0.005 degrees ~ 5 Km
5. Define wave/wind boundary conditions and run SWAN



HANDS ON, MODELLING CYCLONE HAROLD WAVES IN FIJI

1. Go into Harold/Winston folder and open general.swn with a text editor and edit the following lines

```
$$$ startup command
PROJ 'Gen' '01'
$
$$$ General parameters
SET level=0 NAUTICAL
COORDINATES SPHERICAL CCM
$
$$$ Computational grid
CGRID 175.0602 -20.1460 0 7.2000 5.6000 144 112 CIRCLE 36 0.0345 1.00  24
$
$$$ Bathymetry
INPGRID BOTTOM REGULAR 175.0602 -20.1460 0 144 112 0.0497 0.0496 EXC -999
READINP BOTTOM 1 'bot_general.dat' 1 0 FREE
$
$$$ Constant wind definition
WIND 10.00 45.00
$
$$$ Definition of wave boundary conditions
BOUN SHAPE JONSWAP 3.3 PEAK  DSPR  DEGREES
BOUN  SIDE W CON PAR 2.00 10.00 270.00 20
$
$$$ Physics
QUAD
WCAP
BREA
FRICTION JONSWAP
NUM STOPC 0.005 0.01 0.005 95
$
$$$ Grid nesting
$$$ Outputs
BLOCK 'COMPGRID' NOHEAD 'general_grid.mat' LAY 3 XP YP DEP HSIGN TM02 RTP DIR
$
$$$ Lockup commands
TEST  1,0
COMPUTE
STOP
$
```

```
MODE NONSTAT
SET level=0 NAUTICAL
COORDINATES SPHERICAL CCM
```

MODE NONSTAT tells the model to run in nonstationary

HANDS ON, MODELLING CYCLONE HAROLD WAVES IN FIJI

```
$$$ startup command
PROJ 'Gen' '01'
$
$$$ General parameters
SET level=0 NAUTICAL
COORDINATES SPHERICAL CCM
$
$$$ Computational grid
CGRID 175.0602 -20.1460 0 7.2000 5.6000 144 112 CIRCLE 36 0.0345 1.00  24
$
$$$ Bathymetry
INPGRID BOTTOM REGULAR 175.0602 -20.1460 0 144 112 0.0497 0.0496 EXC -999
READINP BOTTOM 1 'bot_general.dat' 1 0 FREE
$
$$$ Constant wind definition
WIND 10.00 45.00
$
$$$ Definition of wave boundary conditions
BOUN SHAPE JONSWAP 3.3 PEAK  DSPR  DEGREES
BOUN  SIDE W CON PAR 2.00 10.00 270.00 20
$
$$$ Physics
QUAD
WCAP
BREA
FRICTION JONSWAP
NUM STOPC 0.005 0.01 0.005 95
$
$$$ Grid nesting
$$$ Outputs
BLOCK 'COMPGRID' NOHEAD 'general_grid.mat' LAY 3 XP YP DEP HSIGN TM02 RTP DIR
$
$$$ Lockup commands
TEST  1,0
COMPUTE
STOP
$
```

INPgrid command defines the domain of the wind field, the resolution and the duration of the time and the time interval the windfields are given (300 sec)

READIN WIND tells SWAN the name of the file where the winds are contained and how to read that file

```
INPgrid WIND REG 175.0 -21.0 0 159 139 0.05 0.05 NONSTAT 20200406.190000 300 SEC
20200410.000000
READINP  WIND 1 'Harold_winds.dat' 3  FREE
```

HANDS ON, MODELLING CYCLONE HAROLD WAVES IN FIJI

```
$$$ startup command
PROJ 'Gen' '01'
$
$$$ General parameters
SET level=0 NAUTICAL
COORDINATES SPHERICAL CCM
$
$$$ Computational grid
CGRID 175.0602 -20.1460 0 7.2000 5.6000 144 112 CIRCLE 36 0.0345 1.00  24
$
$$$ Bathymetry
INPGRID BOTTOM REGULAR 175.0602 -20.1460 0 144 112 0.0497 0.0496 EXC -999
READINP BOTTOM 1 'bot_general.dat' 1 0 FREE
$
$$$ Constant wind definition
WIND 10.00 45.00
$
$$$ Definition of wave boundary conditions
BOUN SHAPE JONSWAP 3.3 PEAK  DSPR  DEGREES
BOUN  SIDE W CON PAR 2.00 10.00 270.00 20
$
$$$ Physics
QUAD
WCAP
BREA
FRICTION JONSWAP
NUM STOPC 0.005 0.01 0.005 95
$
$$$ Grid nesting
$$$ Outputs
BLOCK 'COMPGRID' NOHEAD 'general_grid.mat' LAY 3 XP YP DEP HSIGN TM02 RTP DIR
$
$$$ Lockup commands
TEST  1,0
COMPUTE
STOP
$
```

Delete all these lines as no wave boundary conditions will be used to simulate the cyclones

HANDS ON, MODELLING CYCLONE HAROLD WAVES IN FIJI

```
$$$ startup command
PROJ 'Gen' '01'
$
$$$ General parameters
SET level=0 NAUTICAL
COORDINATES SPHERICAL CCM
$
$$$ Computational grid
CGRID 175.0602 -20.1460 0 7.2000 5.6000 144 112 CIRCLE 36 0.0345 1.00  24
$
$$$ Bathymetry
INPGRID BOTTOM REGULAR 175.0602 -20.1460 0 144 112 0.0497 0.0496 EXC -999
READINP BOTTOM 1 'bot_general.dat' 1 0 FREE
$
$$$ Constant wind definition
WIND 10.00 45.00
$
$$$ Definition of wave boundary conditions
BOUN SHAPE JONSWAP 3.3 PEAK  DSPR  DEGREES
BOUN  SIDE W CON PAR 2.00 10.00 270.00 20
$
$$$ Physics
QUAD
WCAP
BREA
FRICTION JONSWAP
NUM STOPC 0.005 0.01 0.005 95
$
$$$ Grid nesting
$$$ Outputs
BLOCK 'COMPGRID' NOHEAD 'general_grid.mat' LAY 3 XP YP DEP HSIGN TM02 RTP DIR
$
$$$ Lockup commands
TEST  1,0
COMPUTE
STOP
$
```

BLOCK ‘COMGRID’ tells SWAN to save the results in the whole computational grid, the name of the file containing the results, the variables to save, the starting time and the time interval

```
BLOCK 'COMPGRID' NOHEAD 'general_grid.mat' LAY 3 XP YP DEP HSIGN TM02 RTP DIR
OUTPUT 20200406.200000 1.0 HR
```

HANDS ON, MODELLING CYCLONE WINSTON AND HAROLD WAVES IN FIJI

```
$$$ startup command
PROJ 'Gen' '01'
$
$$$ General parameters
SET level=0 NAUTICAL
COORDINATES SPHERICAL CCM
$
$$$ Computational grid
CGRID 175.0602 -20.1460 0 7.2000 5.6000 144 112 CIRCLE 36 0.0345 1.00  24
$
$$$ Bathymetry
INPGRID BOTTOM REGULAR 175.0602 -20.1460 0 144 112 0.0497 0.0496 EXC -999
READINP BOTTOM 1 'bot_general.dat' 1 0 FREE
$
$$$ Constant wind definition
WIND 10.00 45.00
$
$$$ Definition of wave boundary conditions
BOUN SHAPE JONSWAP 3.3 PEAK  DSPR  DEGREES
BOUN  SIDE W CON PAR 2.00 10.00 270.00 20
$
$$$ Physics
QUAD
WCAP
BREA
FRICTION JONSWAP
NUM STOPC 0.005 0.01 0.005 95
$
$$$ Grid nesting
$$$ Outputs
BLOCK 'COMPGRID' NOHEAD 'general_grid.mat' LAY 3 XP YP DEP HSIGN TM02 RTP DIR
$
$$$ Lockup commands
TEST  1,0
COMPUTE
STOP
$
```

COMPUTE NONSTAT, tells SWAN to run in nonstationary mode from the starting date, each 1800 sec to the final date

Times here are for Harold, for Winston use:

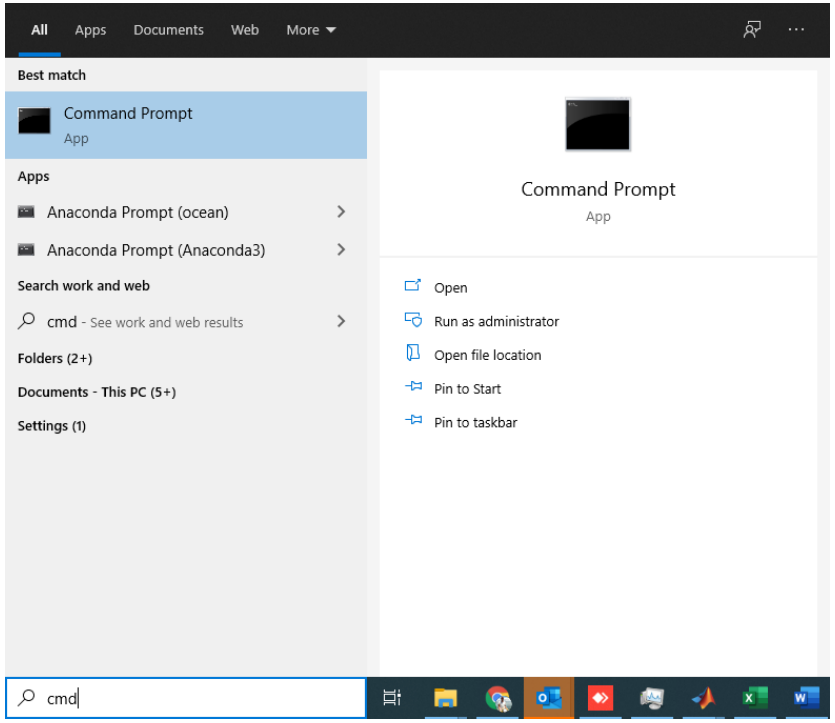
XXX

COMPUTE NONSTAT 20200406.200000 1800 SEC 20200410.000000

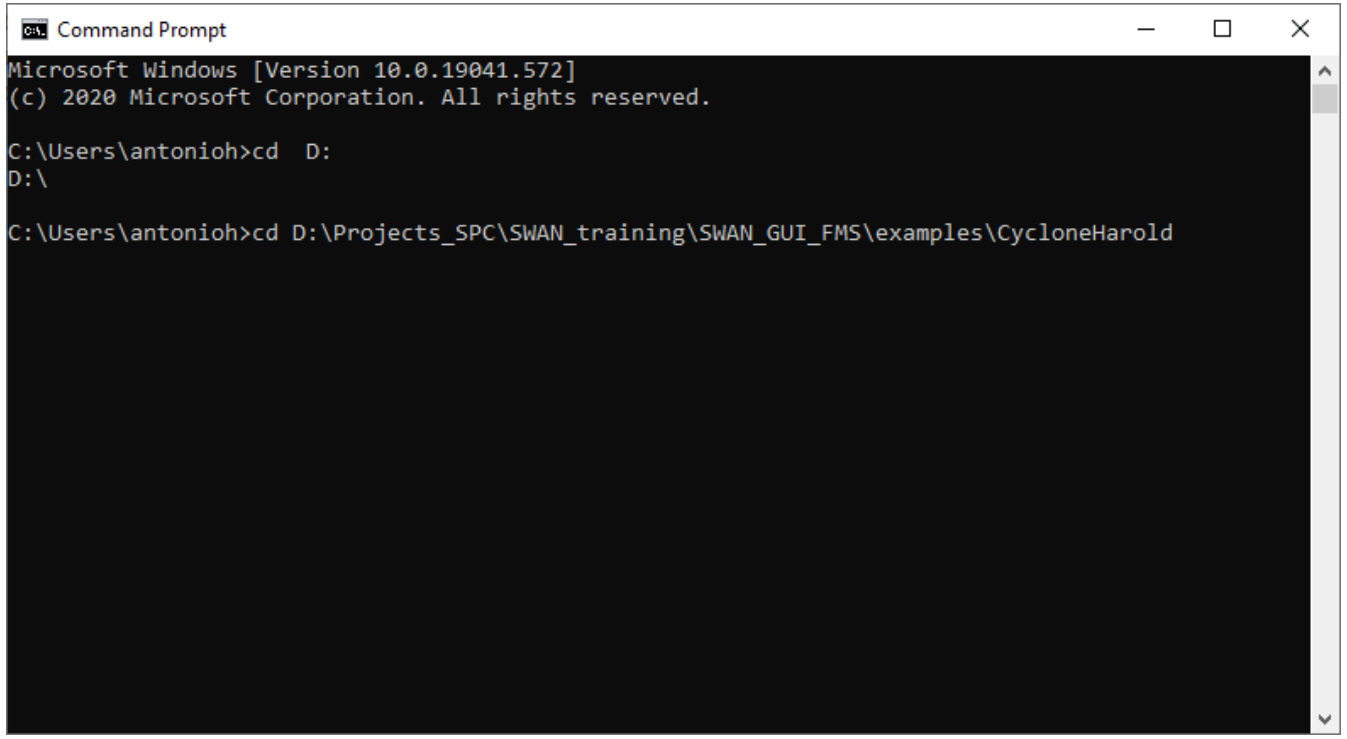
HANDS ON, MODELLING CYCLONE WINSTON AND HAROLD WAVES IN FIJI

Run SWAN from the cmd

1. Open Command Prompt



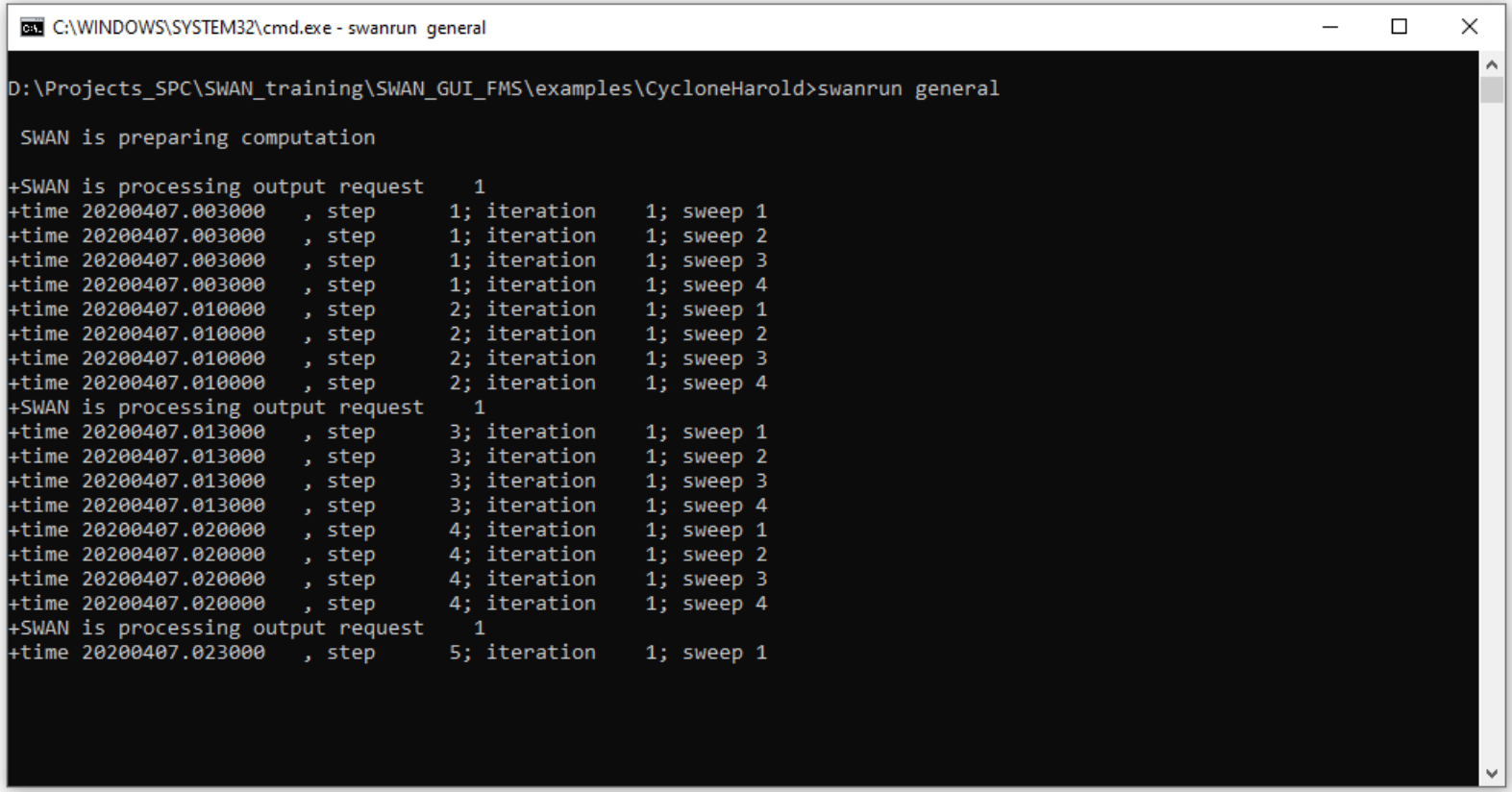
2. Go to your directory



HANDS ON, MODELLING CYCLONE WINSTON AND HAROLD WAVES IN FIJI

Run SWAN from the cmd

swanrun general



HANDS ON, MODELLING CYCLONE WINSTON AND HAROLD WAVES IN FIJI

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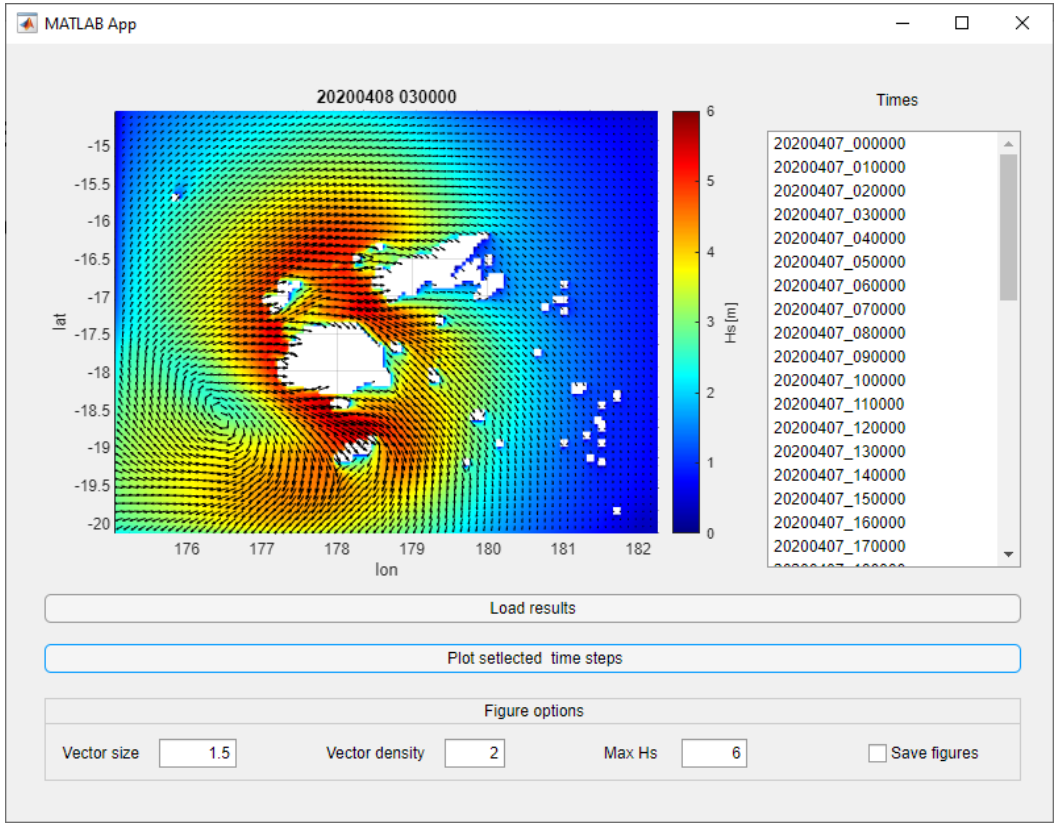
Run SWAN_GUI_FMS_Installer_web.exe inside the GUI folder and plot the results

- Arrows size and density can be modified
- Set up maximum Hs
- Figures can be exported



SPC’S TC HAROLD WAVE AND STORM SURGE MODEL

TC HAROLD

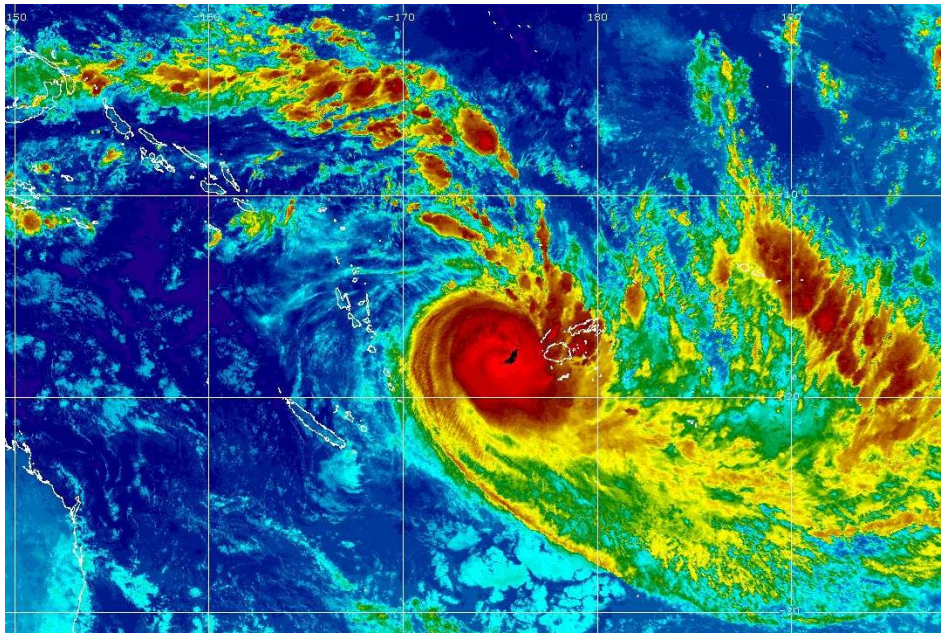
- On April 2020, TC Harold caused widespread destruction In Solomon, Vanuatu, Fiji and Tonga

- Max sustained winds of 220 Km/h and gust of 270 Km/h

OBJECTIVES

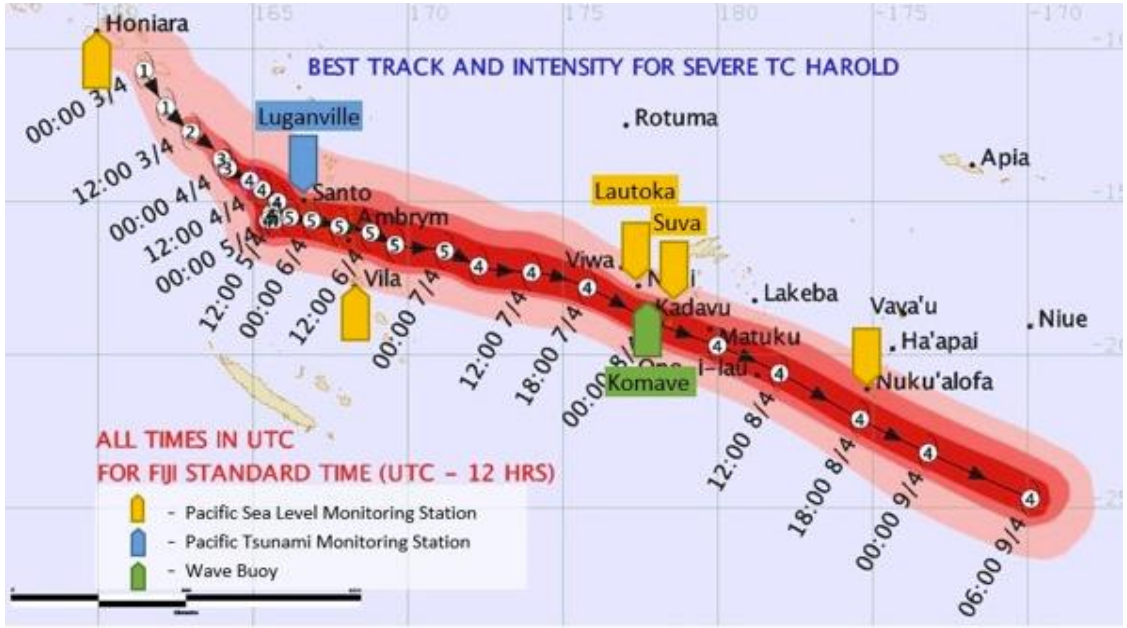
- Provide reliable information to the post disaster field survey team about the areas most affected in terms of winds, waves and storm surge

- Demonstrate that the state of the art technologies to build up impact based forecast system for TC are available in the region



What input do we need to build an accurate storm surge and wave model?

- Best possible bathymetry and topography
- Astronomical tide forecast
- Mean sea level forecast
- **A reliable track forecast:**
  - **Position**
  - **Intensity (wind and pressure)**
  - **Size (radius of maximum winds)**

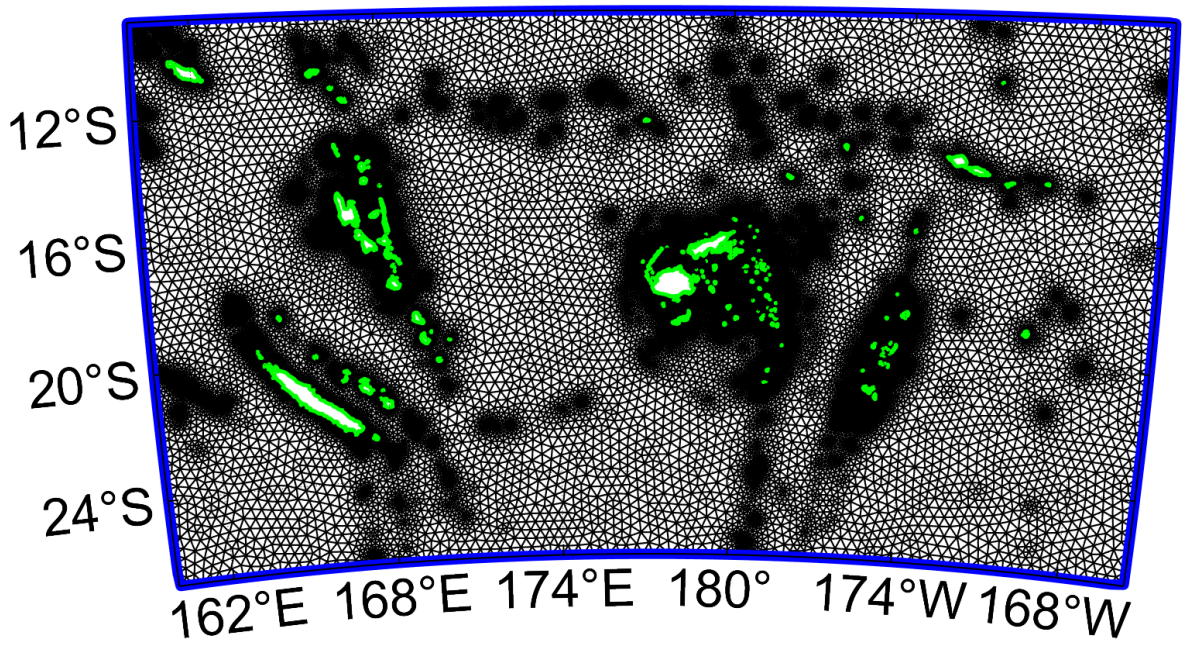


SPC's storm surge and wave model, what is different from other models?

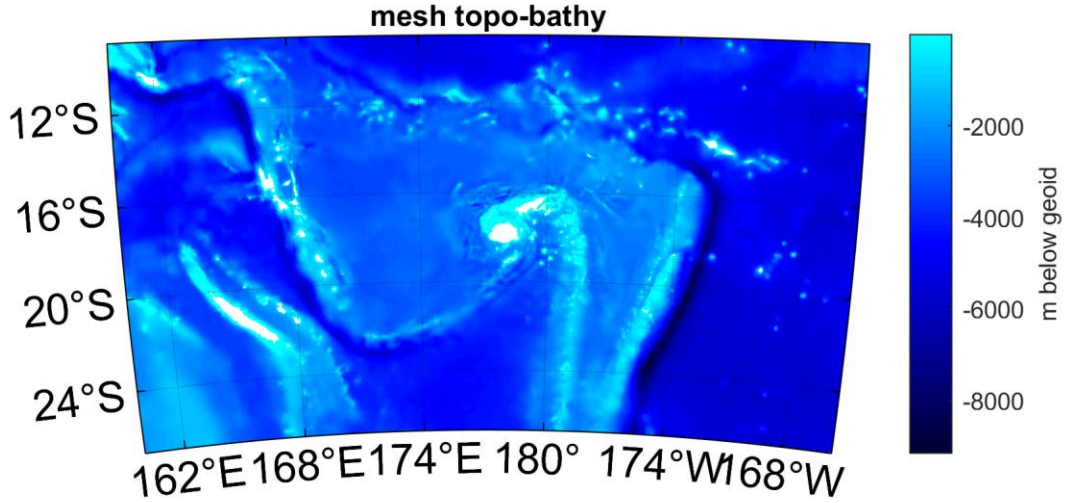
- Coupled ADCIRC+SWAN model : all dynamics are run together, hydrodynamics + waves
- ADCIRC+SWAN is the models used in the US territories (including the Caribbean) to forecast coastal inundation
- It works in non-structured mesh so resolution is variable doing the model highly efficient:
    - coarse resolution in open ocean
    - Super high resolution on the coast: better to resolve complex coast forms and small islands
- It is parallelizable: good computational times
- It resolves inundation overland if good topography is provided
- It resolves the wave set up but not the infragravity waves!!!! Empirical formulation can be used to estimate this part of the inundation process in reef fronted coasts

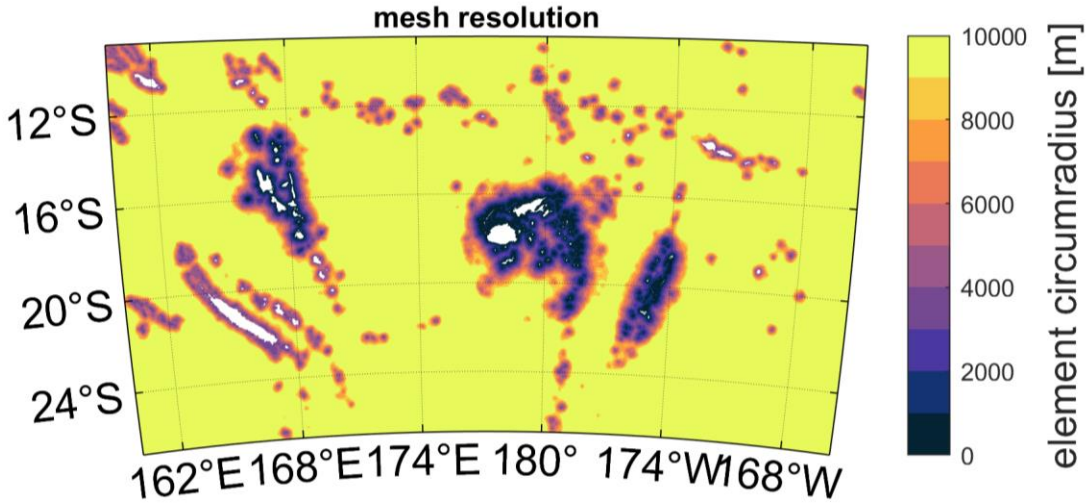
SPC's storm surge and wave model

- Contains 180.340 nodes
- Covers 3.400 Km in longitude by 1.970 in latitude
- Resolution ranges from 15 Km in the deep ocean to 300-500 m along the coasts of Vanuatu, Fiji and Tonga



SRTM_15_PLUS



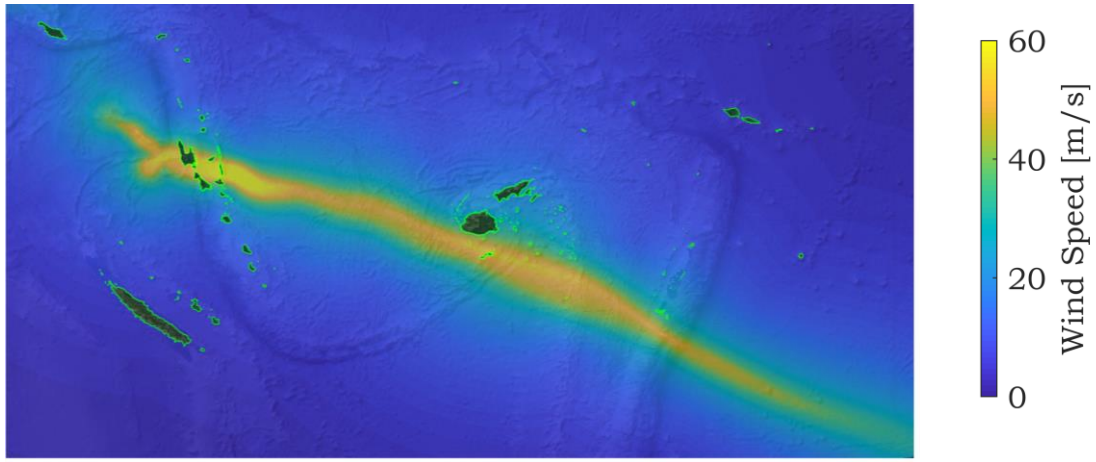


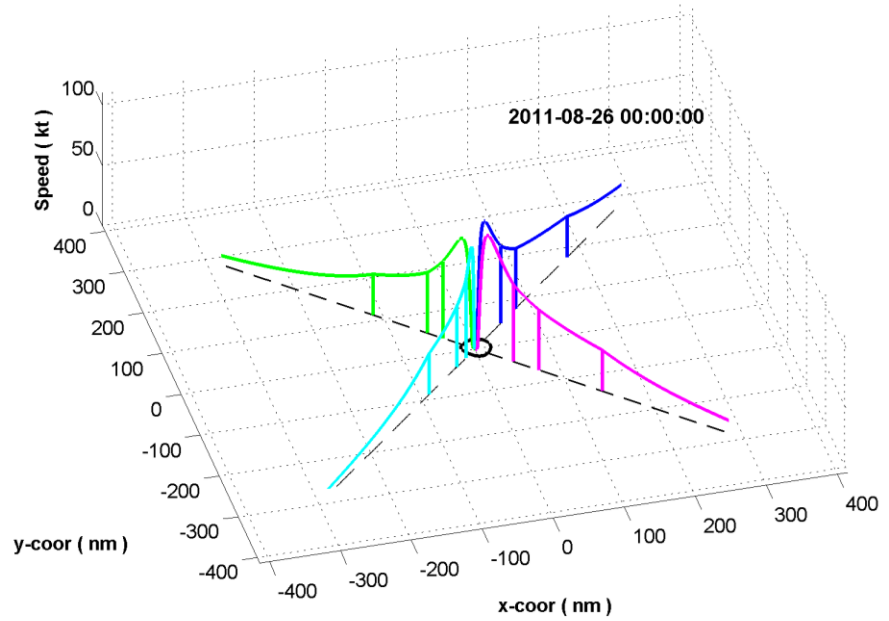
SPC's storm surge and wave model

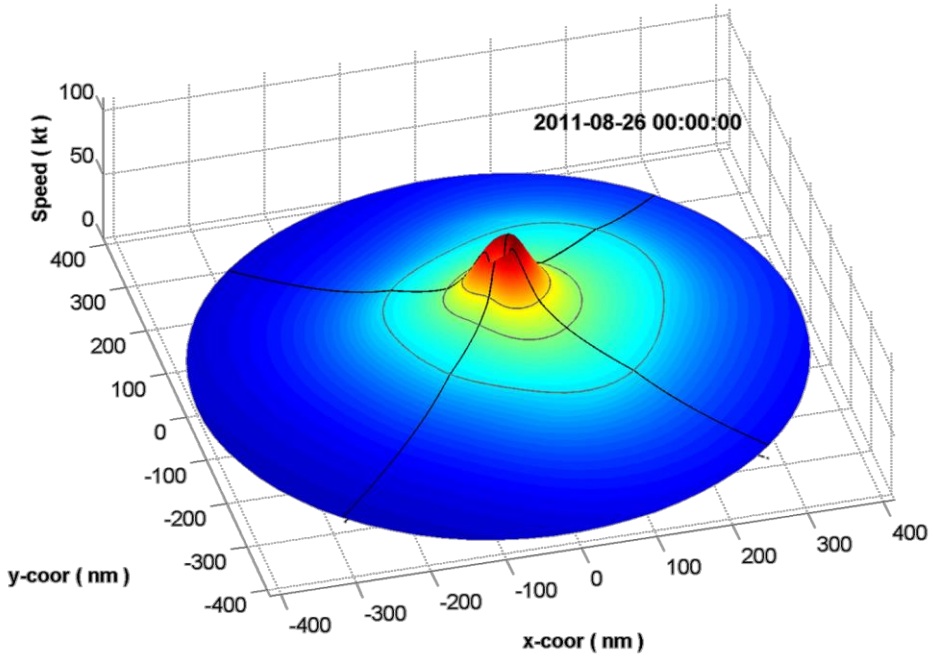
Parametric WIND model

TC wind fields can be reproduced with relatively easy parametric models:

- Track: longitude, latitude
- Maximum wind
- Minimum pressure
- Size: radius of maximum winds, Rmax
- Rmax for each quadrant

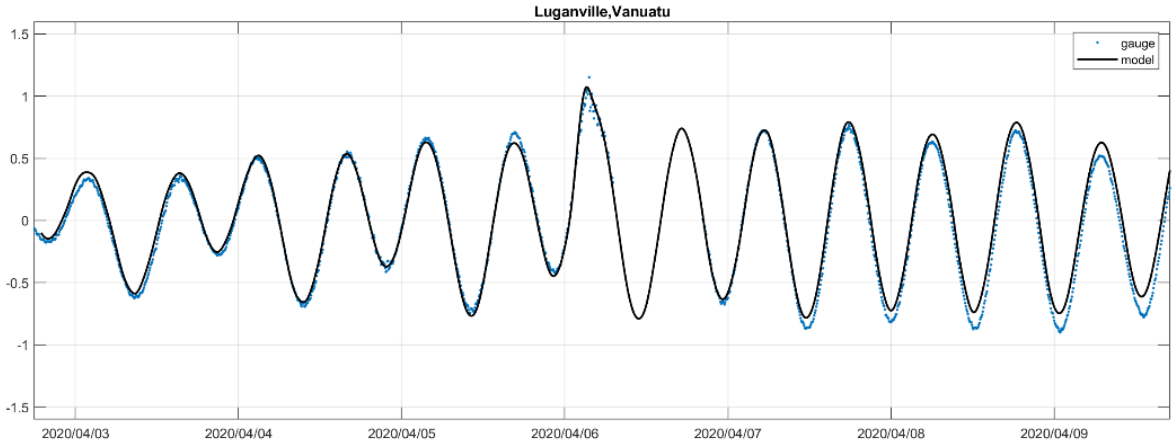


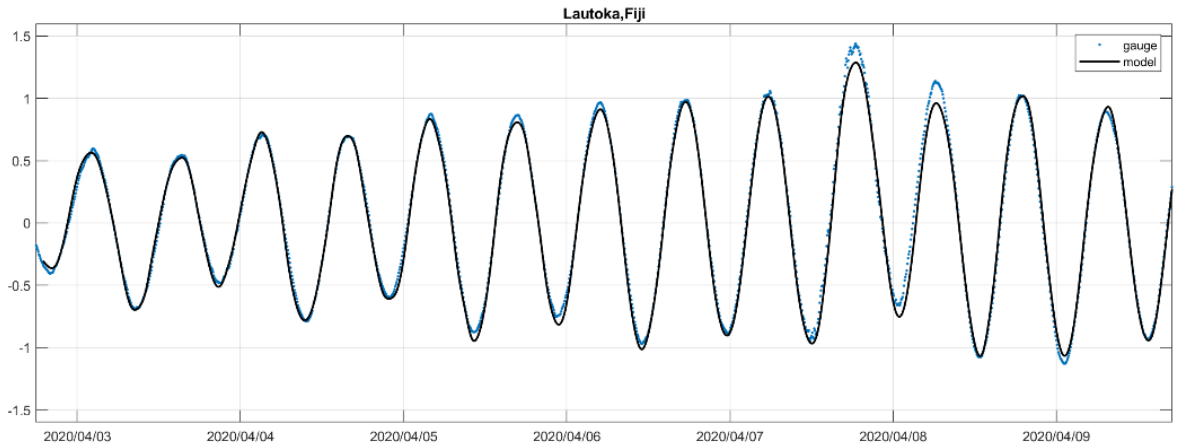


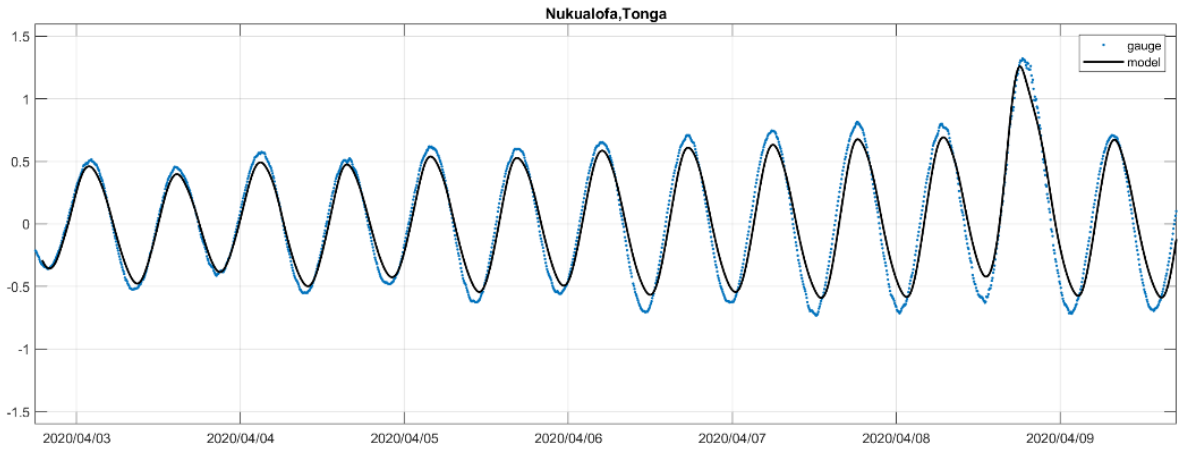


SPC's storm surge and wave model

Validation of water levels with tide gauges

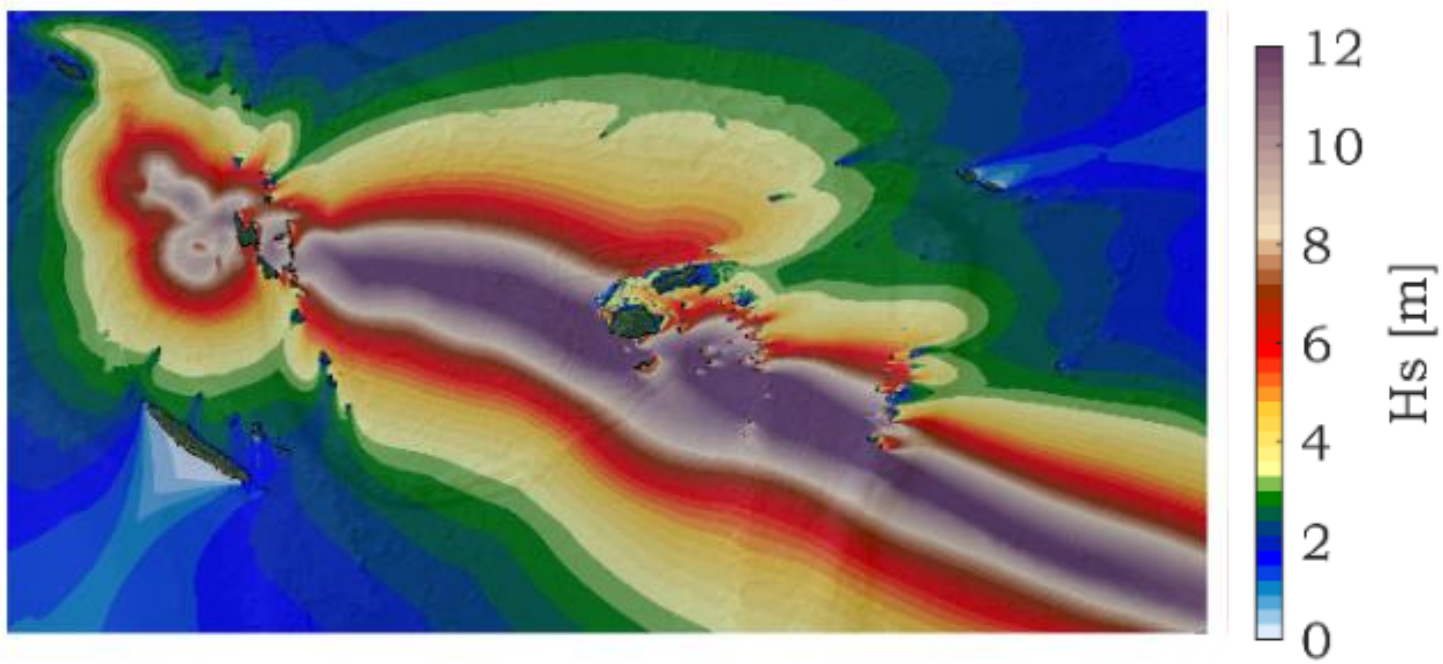


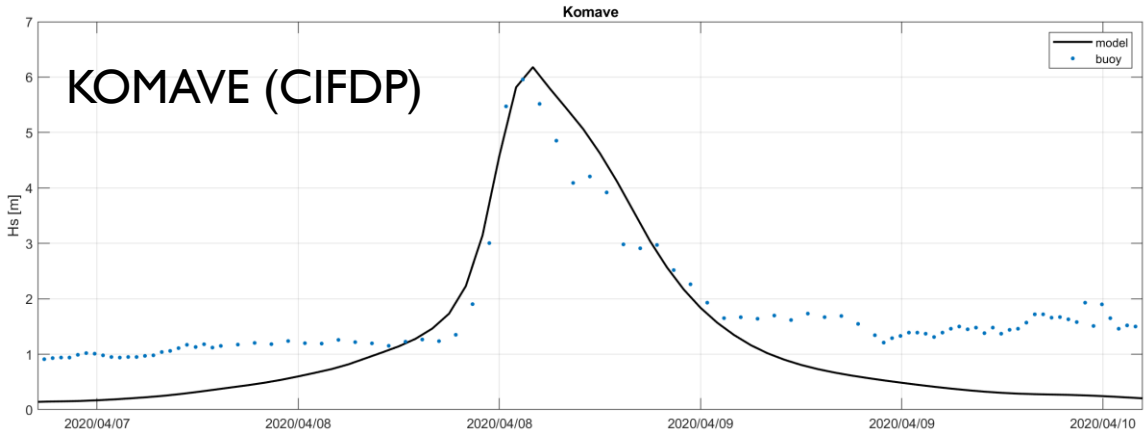


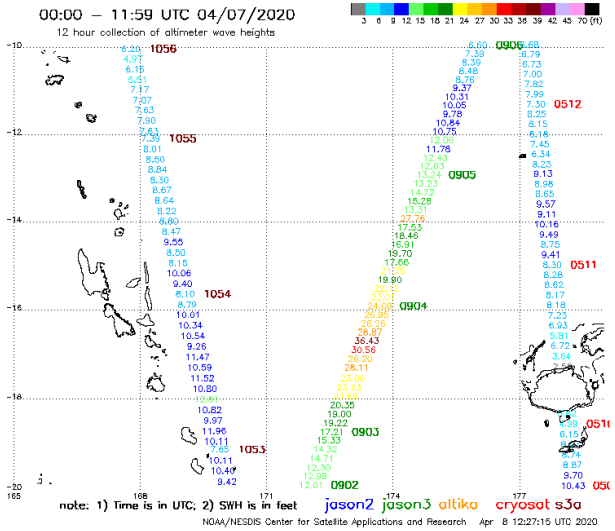


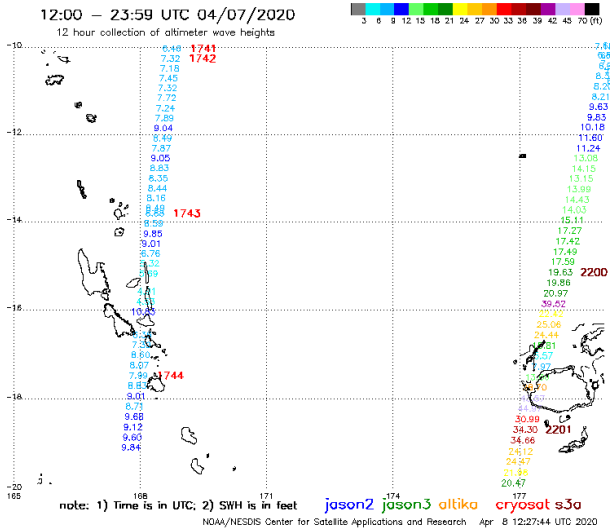
SPC's storm surge and wave model

Validation of waves with satellite and wave buoy



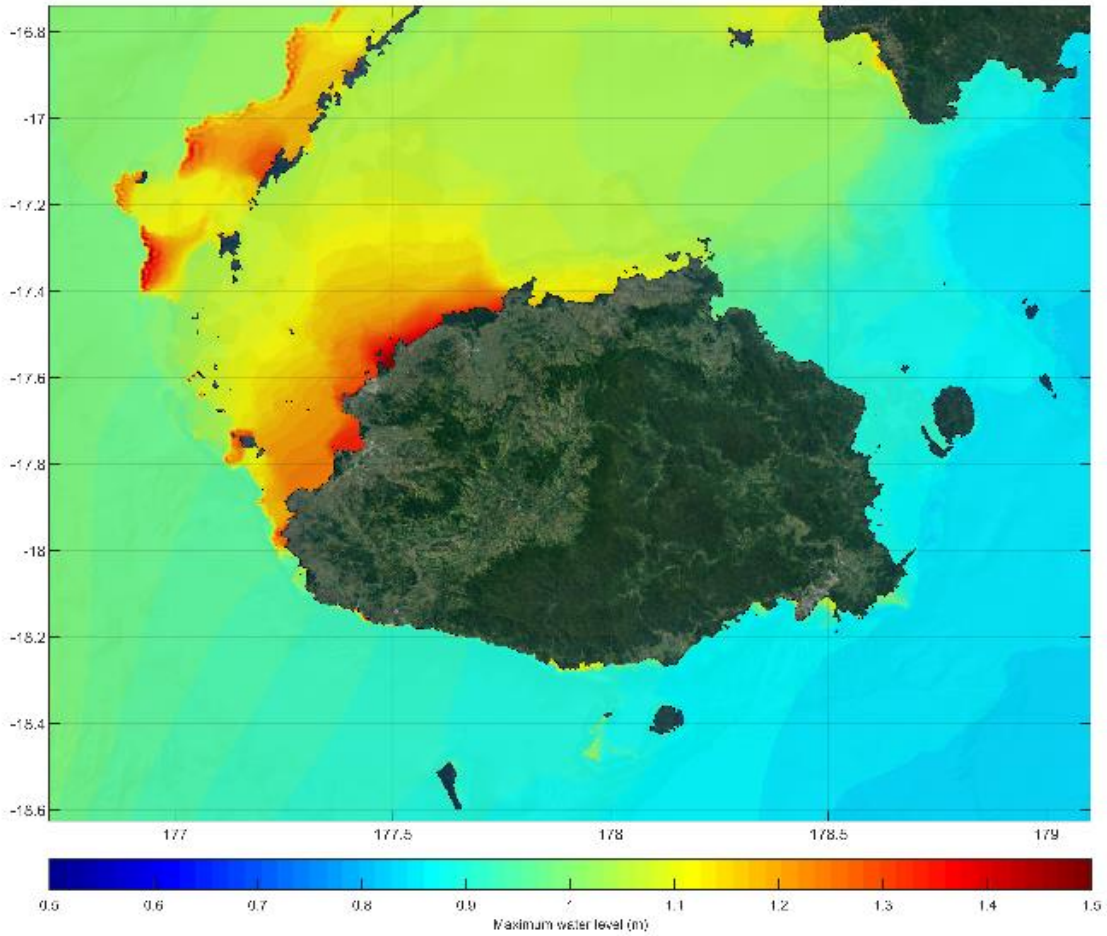


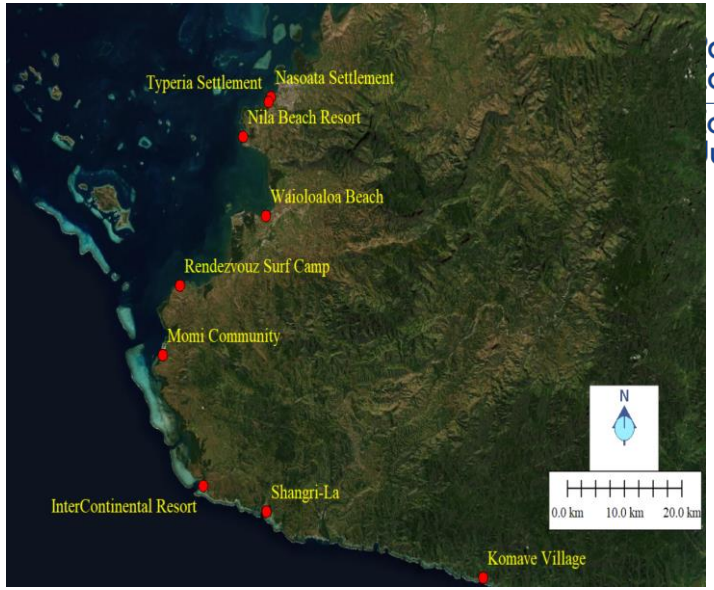




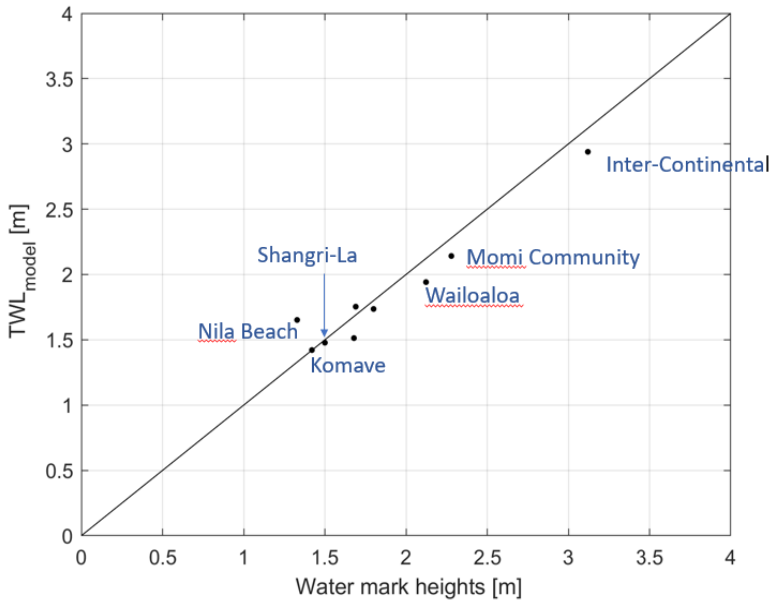
SPC's storm surge and wave model

Validation of inundation with high water marks





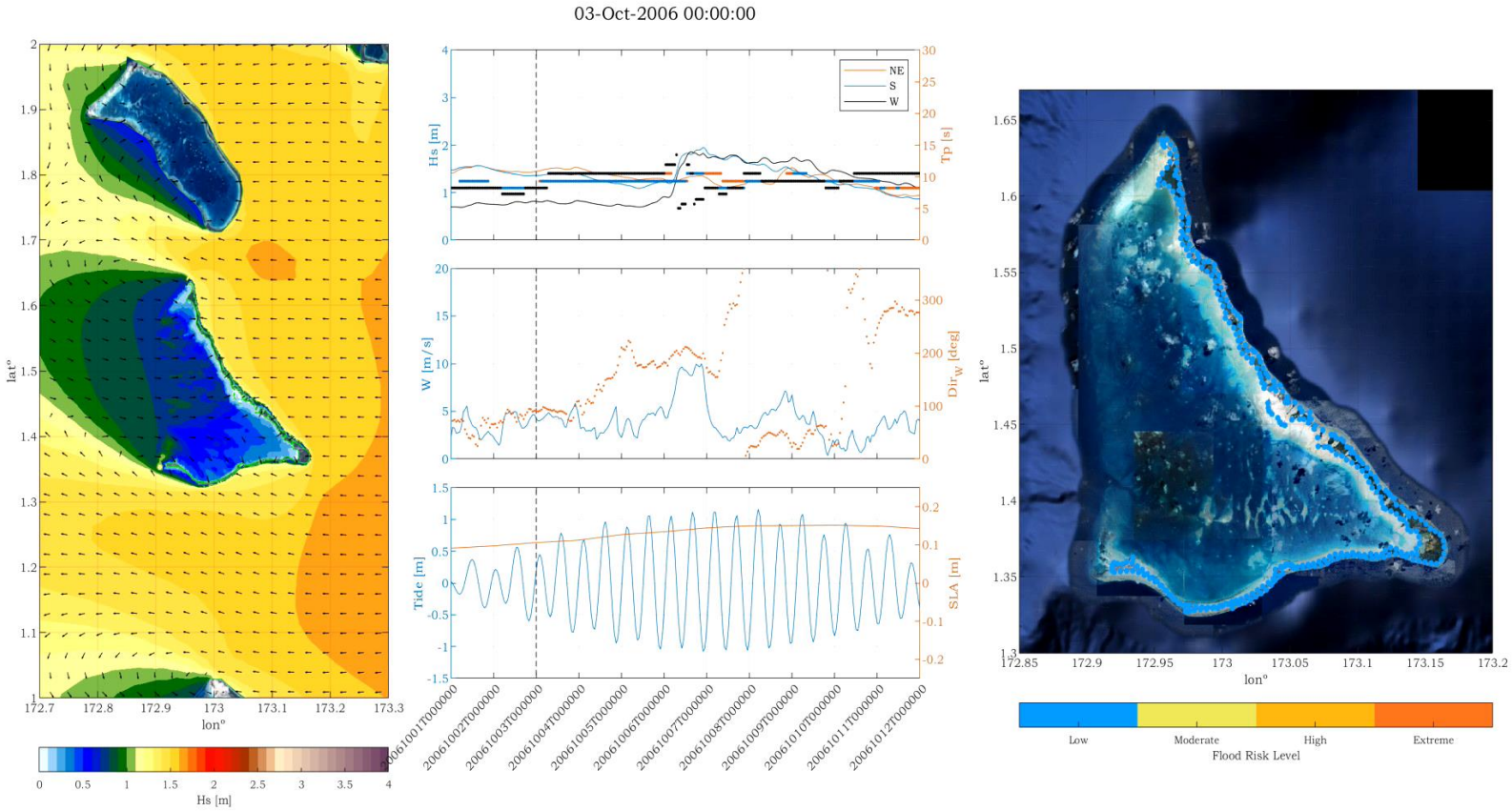
$$R_2 = 0.73\beta_f (H_0 L_0)^{1/2}$$



SPC's storm surge and wave model

Other examples, Tarawa inundation forecast (CREWS):

- SPC developed an innovative inundation warning system for Tarawa
- Tailored to areas with poor baseline data
- Could be applicable to national scale inundation early warning systems



Next steps to build up an operational storm surge and wave model:

- SPC is eager to support FMS TC warning activities for the upcoming season

- Need to discuss about the data needed to run the model and what FMS needs as a product

- Medium term activities:

    - Improve baseline data: beach profiles, reef geomorphology

    - Possibility if coupling of CIFDP inundation forecast system

    - Possibility of improving with machine learning algorithms

    - Possibility to increase resolution in flood prone areas (Nadi bay)

    - Extend the model to all countries under FMS area of responsibility

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SWAN WAVE MODEL

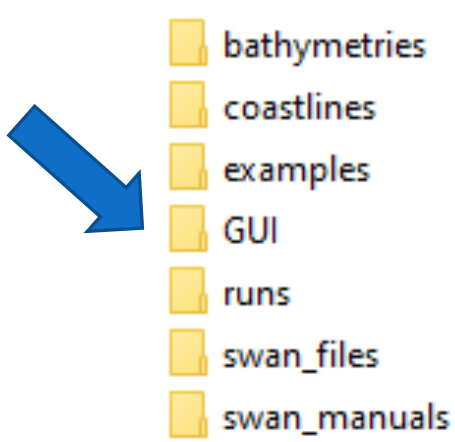
GRAPHICAL USER INTERFACE - MANUAL

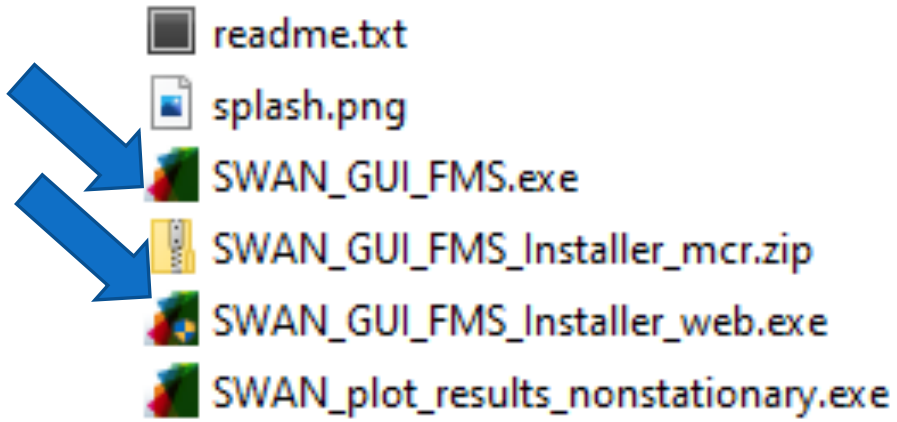
INSTALLATION STEPS

1. Unzip and copy the SWAN_GUI to your PC, path needs to be without spaces.

2. Install Matlab Runtime inside GUI folder: SWAN_GUI_Installer_web.exe (needs internet connection, it may take some time) or SWAN_GUI_Installer_mcr.zip

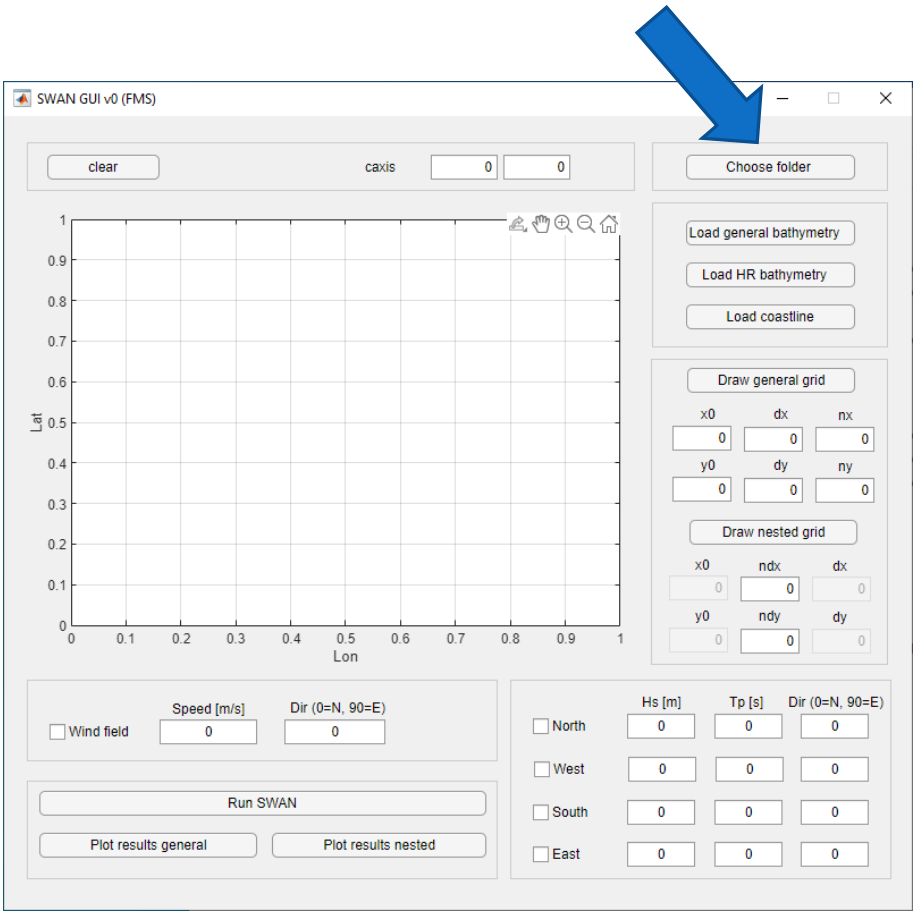
3. Open SWAN GUI: SWAN_GUI.exe

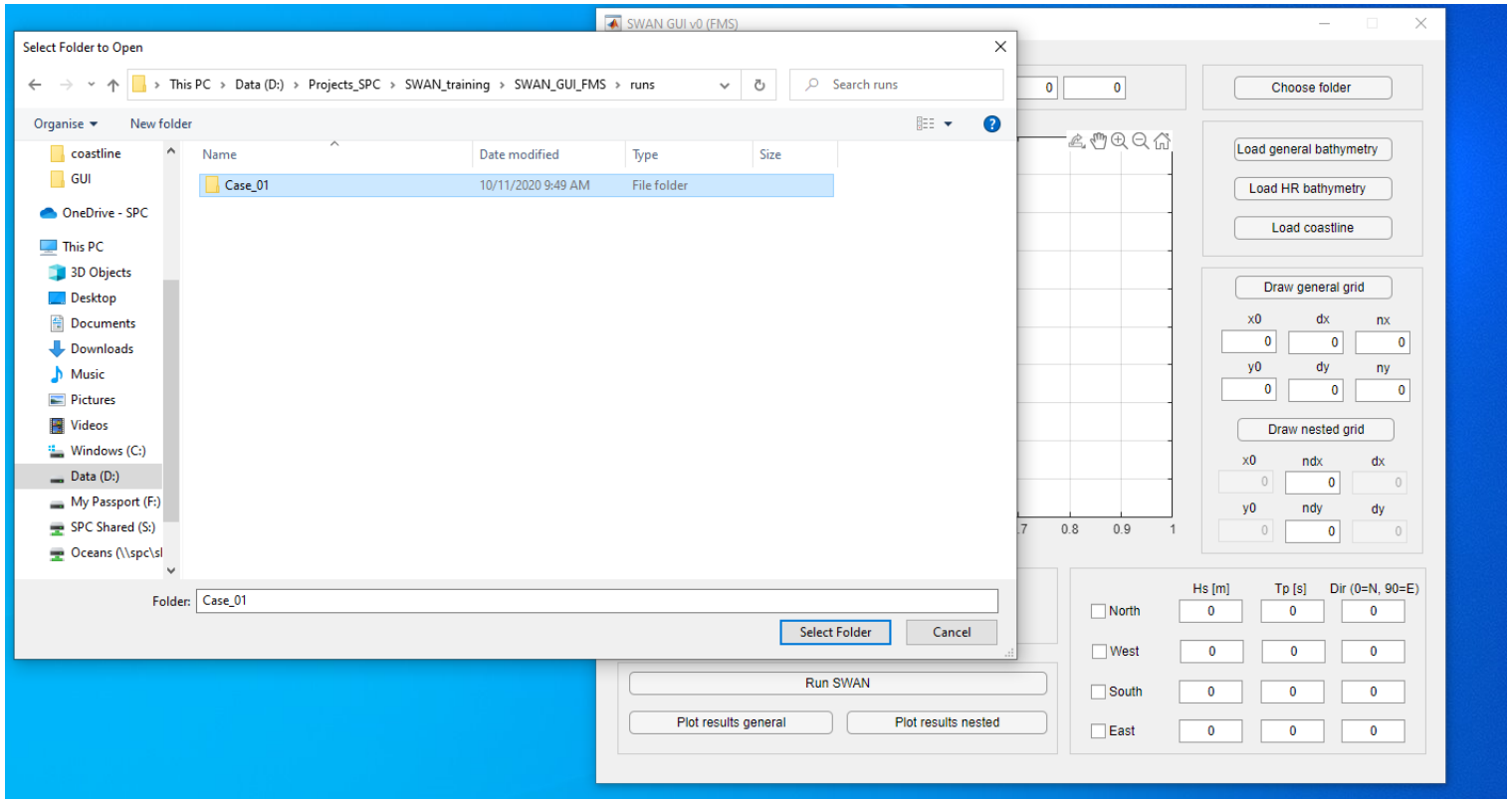




STEP1: Create your working environment

1. Create/choose a folder where a SWAN simulation will be run. It is desirable to run each case in a different folder within the run folder





STEP2: Load your bathymetry data

- The GUI supports the importing of a maximum of two bathymetry datasets (with identical projection), a global and a high resolution datasets. **At least one bathymetry file must be imported to run the wave model.**

  - Bathymetry file (file extension *.xyz) is a three column file formatted as follow:

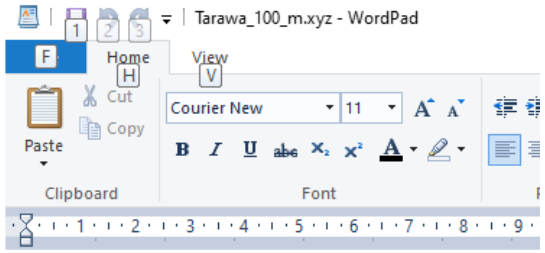
  x/Lon/Easting, y/Lat/Northing, depth (positive)
  Note that file is comma delimited with no header

  - The bathymetry files should be located in the folder named bathymetries (it will be easy to find them).

- **Load general bathymetry** button**:** Use to load the coarse bathymetry. It is also used to load HR bathymetry file if only one bathymetry file is loaded.

- **Load general Bathymetry** button: Use to load the HR bathymetry if a general bathymetry file (coarser) was already provided. If loaded, the HR bathymetry is highlighted by a red bounding box in the GUI.

- **Load coastline** button: Use to import coastline into the GUI. The software can read 2 common coastline file format: shapefile polygon or polyline as exported from QGIS.



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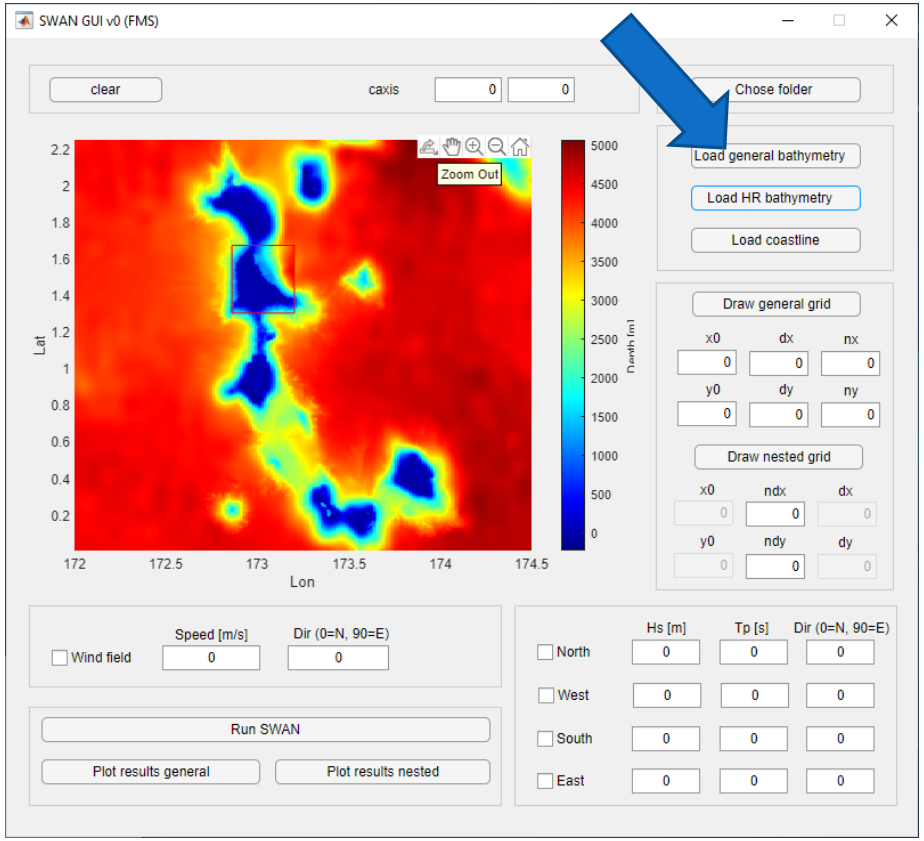
```
172.8608548,1.673313151,2763.69
172.8617541,1.673313151,2762.55
172.8626534,1.673313151,2762.55
172.8635527,1.673313151,2754.03
172.864452,1.673313151,2745.07
172.8653513,1.673313151,2726.91
172.8662506,1.673313151,2719.89
172.8671499,1.673313151,2713.94
172.8680492,1.673313151,2676.66
```

Example of the bathymetry file



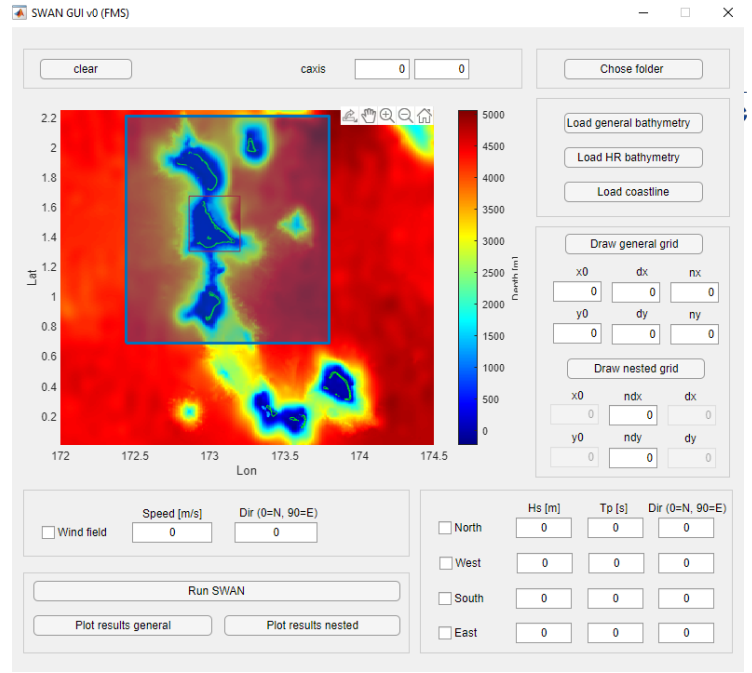
STEP3: Define your computational domain

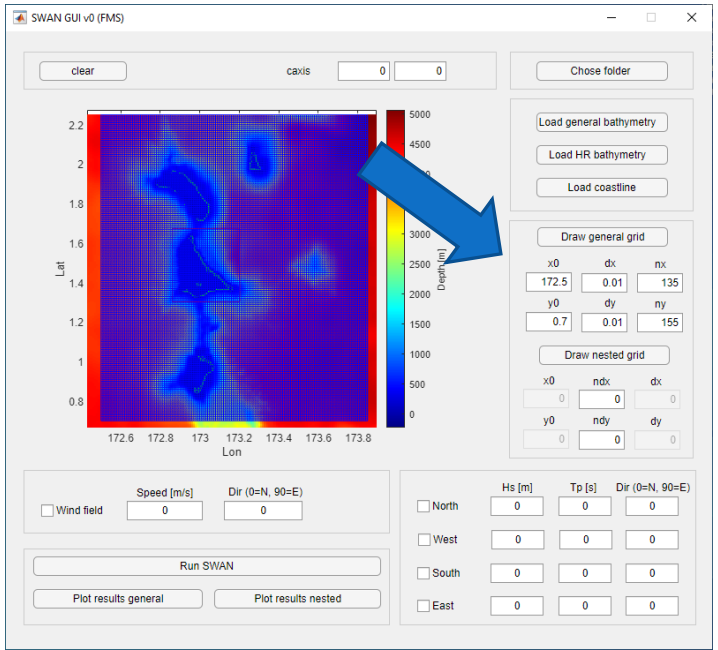
Nesting: In order to gain efficiency, it is convenient to first propagate the waves towards the study site using a coarse grid. The waves from the coarse grid are then fed into the higher resolution grid (or nested grid) covering the area of interest where accuracy is most needed.

Draw the general grid button**:** Use to define the extent of the general grid/computational domain.

- Press the **Draw general grid** button and drag over the desired area.
- The grid can be refined using the following parameters:
  - Origin (X0,Y0)
  - Grid Spacing / resolution (dx,dy)
  - Number of Cells in x and Y directions (nx, ny)

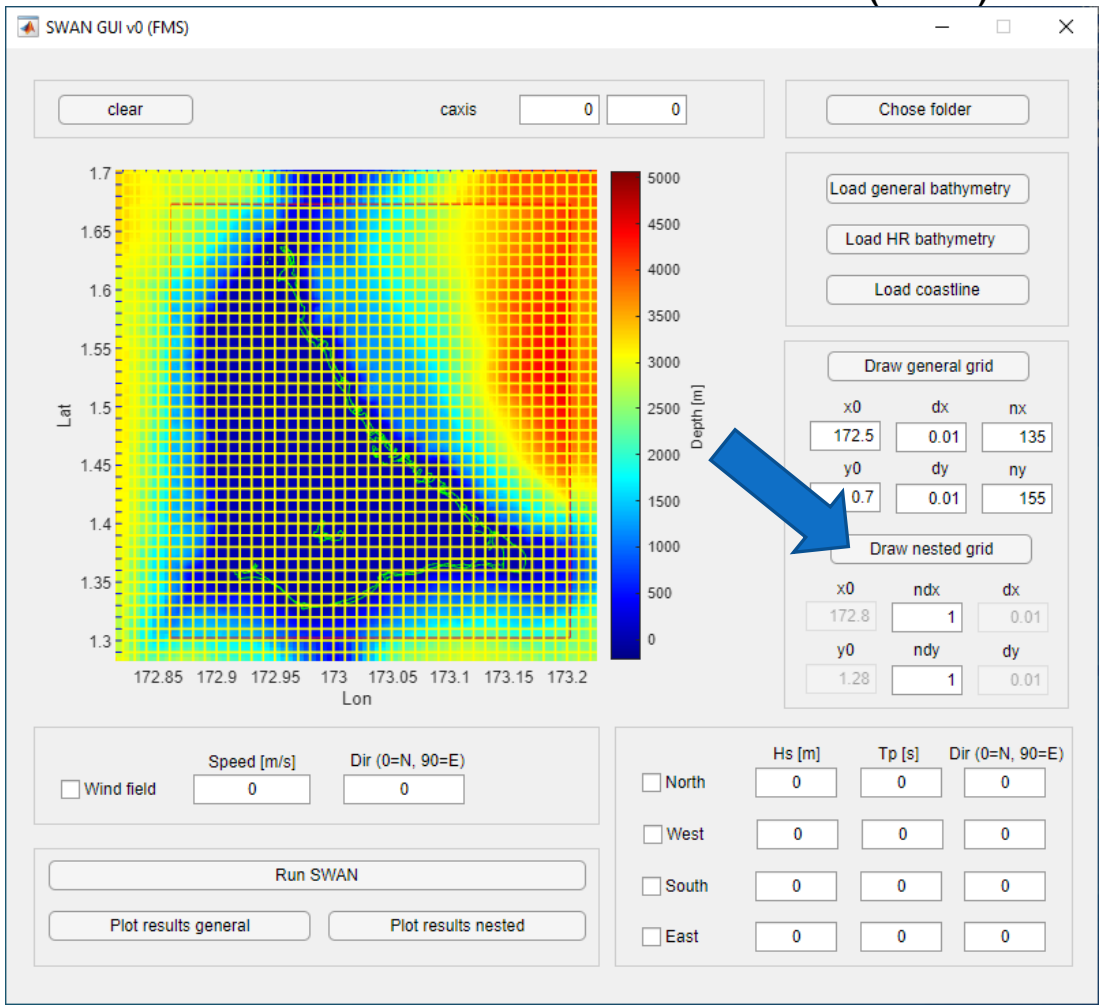
- Note that the general grid can be generated without the need of using the free hand tool but by simply defining it numerically. In this example dx and dy have been set to 0,01 degrees (about 1 Km over the 3 Gilbert Islands) obtaining 135 cells in X and 155 in Y directions.

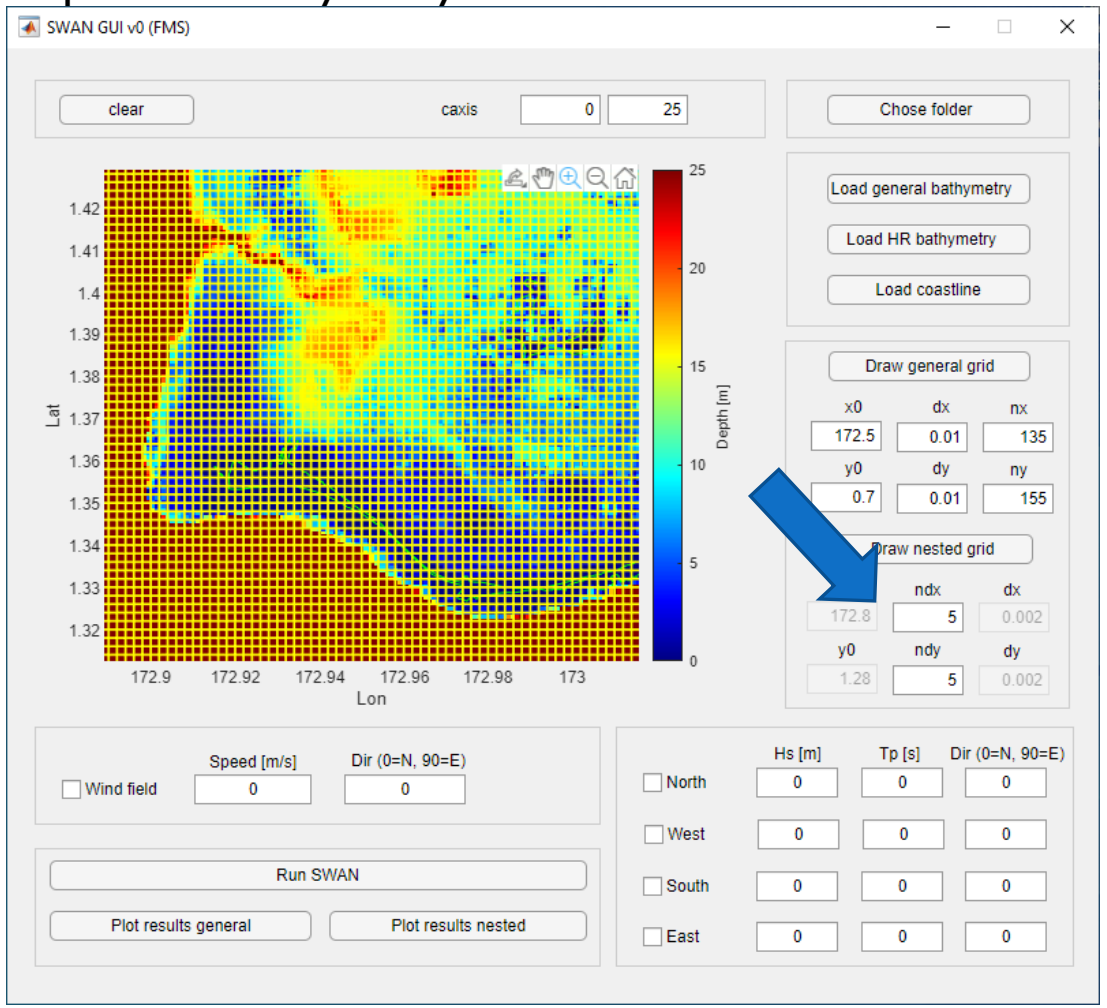




STEP3: Define the nested computational domain

- **Draw nested grid** button: Use to define the extent of the HR grid/HR computational domain. Define the HR grid resolution as a subdivision of the general grid (ndx and ndy). In this case it is set to 5 so that HR grid for Tarawa is 250m resolution (1km/5)
- Note that the colour scale can be modified (caxis) to better inspect the bathymetry dataset.



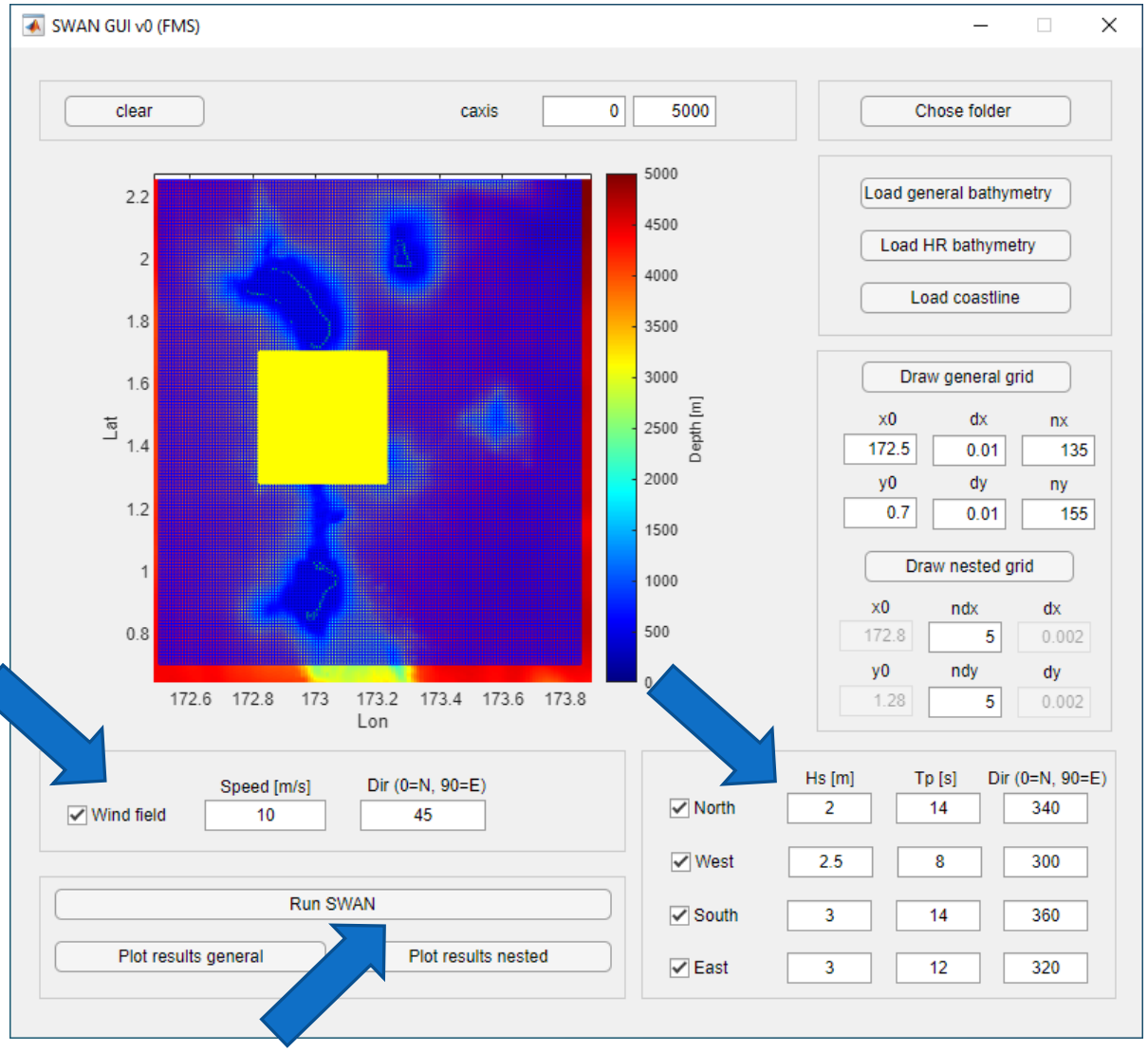


STEP4: Define the wave and/or wind forcing

- Define wave boundary conditions for each side of the general grid
  - Hs: significant wave height
  - Tp: Peak period
  - Dir: Mean direction

- Define constant wind
  - Speed
  - Direction

- Run SWAN button: Use to start the model run



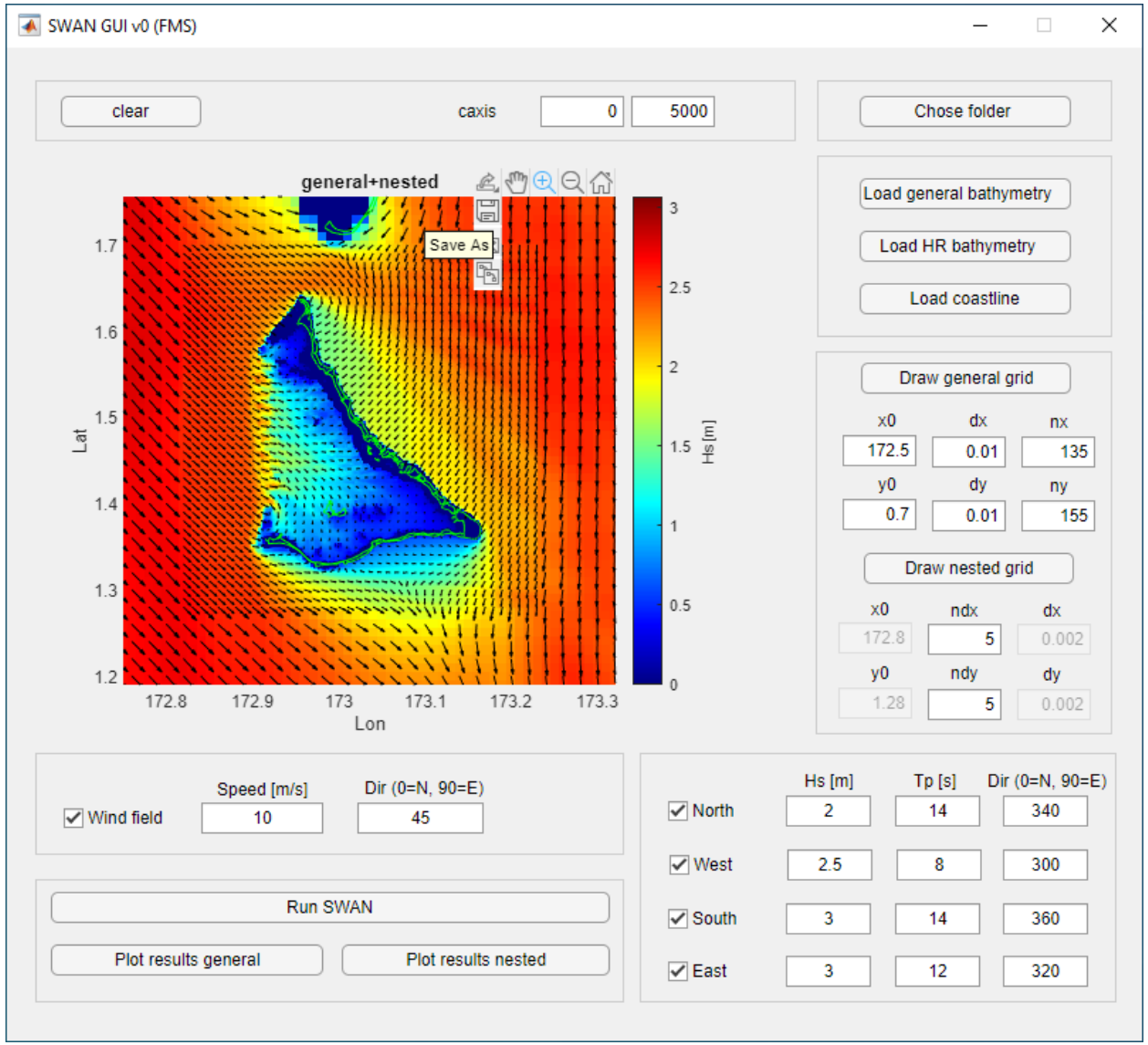
STEP5: Investigate the model output

- **Plot result general** button: Use to plot the result from the general wave model as a 2D map of the wave height and direction.

- **Plot result nested** button: Use to plot the result from the HR wave model as a 2D map of the wave height and direction.

- The colour scale can be adjusted (caxis) to better represent wave gradients in the area of interest.

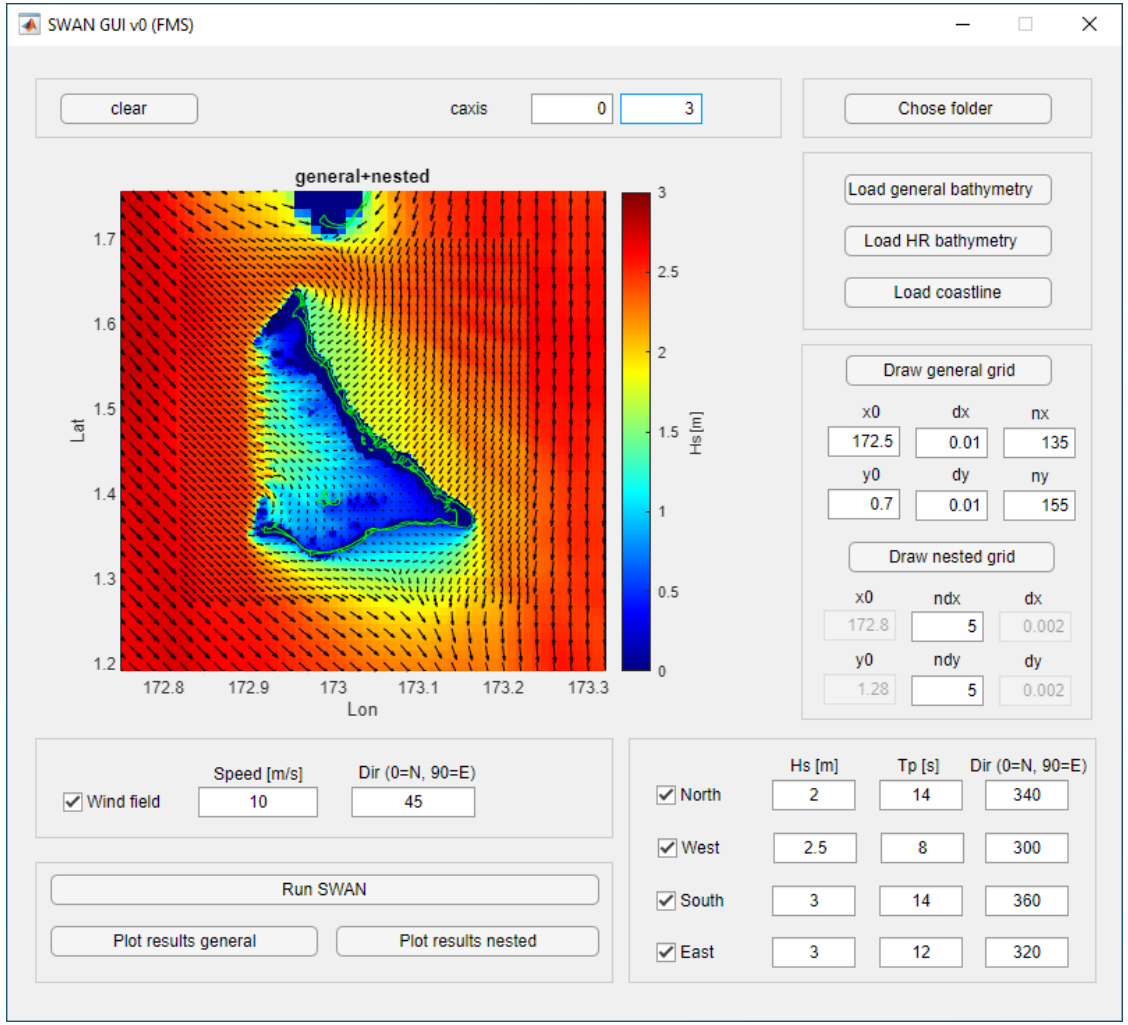
- The result can be exported as …

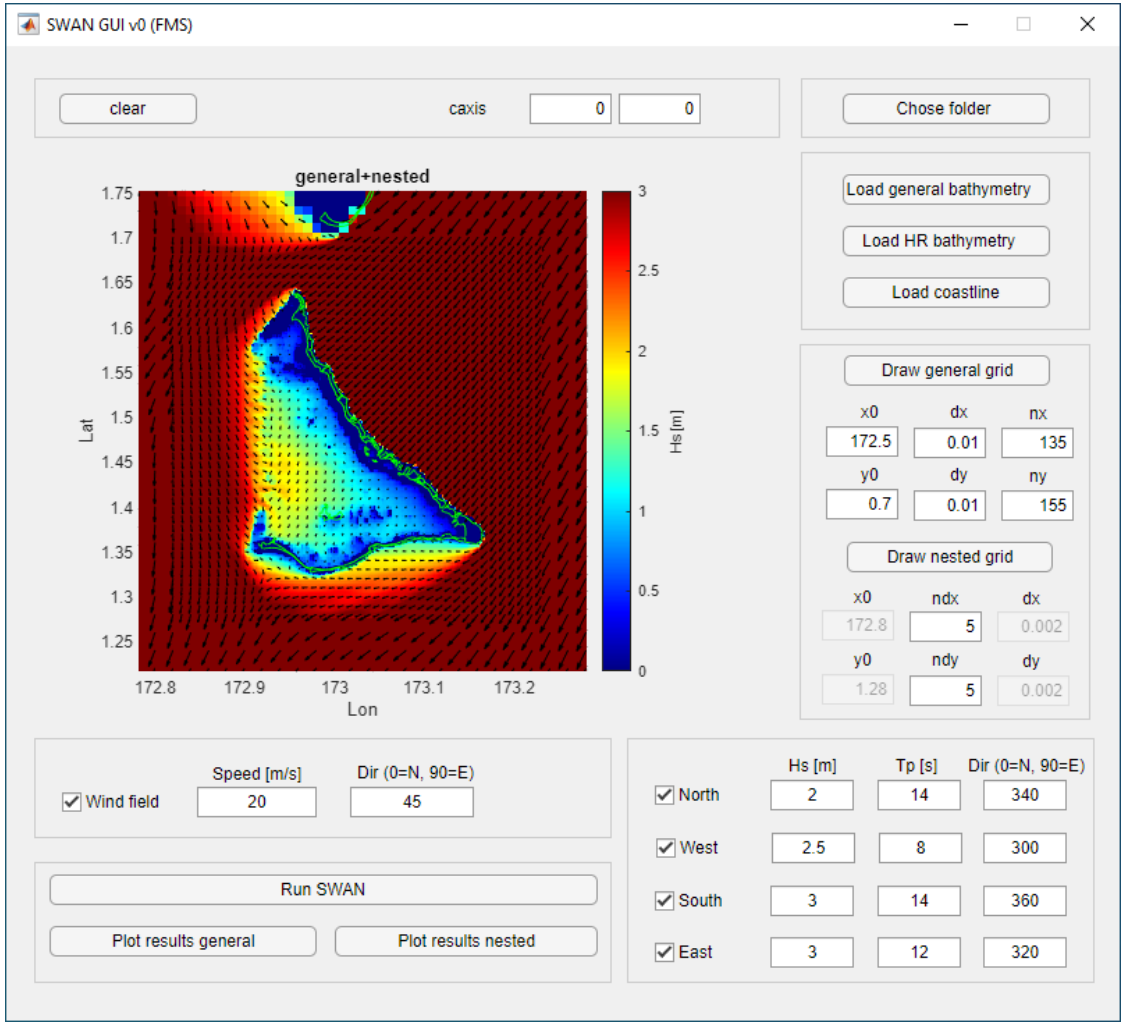


Tips: Run a new scenario

- For each new case, it is recommended to create a new folder using the **Choose folder** button.

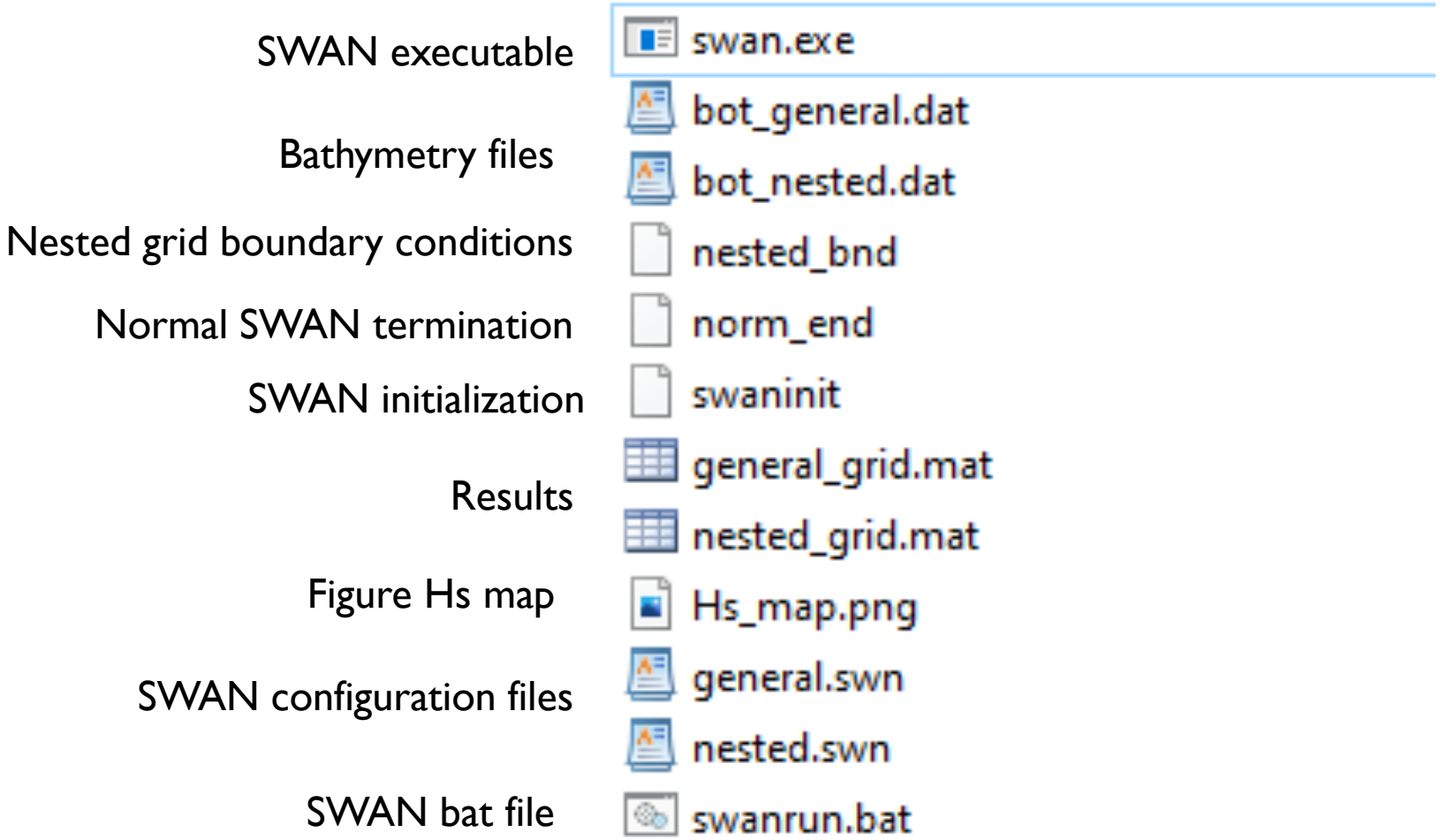
In the below example, 2 scenarios are run using different folder.





Exploring SWAN files for advanced user

- In each folder a set of files are generated, this files can be used to further improve the simulation with more sophisticated settings (i.e. variable boundary conditions, non-stationary runs, etc.)



Exploring SWAN files for advanced user

- The SWAN configuration files (*.swn) can be modified to change the model forcing, physics or outputs. For this task is recommended checking the SWAN User Manual inside the swan_manual folder

Project name and run

```
$$$ startup command
PROJ 'Gen' '01'
$
```

General settings

```
$$$ General parameters
SET level=0 NAUTICAL
COORDINATES SPHERICAL CCM
$
```

Computational domain

```
$$$ Computational grid
CGRID 175.2000 -20.0000 0 6.9500 5.4000 139 108 CIRCLE 36 0.0345 1.00  24
$
```

Bathymetry

```
$$$ Bathymetry
INPGRID BOTTOM REGULAR 175.2000 -20.0000 0 139 108 0.0496 0.0495 EXC -999
READINP BOTTOM 1 'bot_general.dat' 1 0 FREE
$
```

Wind forcing

```
$$$ Constant wind definition
WIND 8.00 70.00
$
```

Wave forcing

```
$$$ Definition of wave boundary conditions
BOUN SHAPE JONSWAP 3.3 PEAK  DSPR  DEGREES
BOUN  SIDE W CON PAR 2.00 15.00 200.00 20
BOUN  SIDE S CON PAR 2.00 15.00 200.00 20
$
```

Physics

```
$$$ Physics
QUAD
WCAP
BREA
FRICTION JONSWAP
NUM STOPC 0.005 0.01 0.005 95
$
```

Nesting

```
$$$ Grid nesting
$$$ Outputs
BLOCK 'COMPGRID' NOHEAD 'general_grid.mat' LAY 3 XP YP DEP HSIGN TM02 RTP DIR
$
```

Lockup commands

```
$$$ Lockup commands
TEST  1,0
COMPUTE
STOP
$
```