Australian Government | Australian Climate Service

WHACS: A new global **Wave Hindcast** for the **Australian Climate Service**

Grant Smith
Alberto Meucci
Stefan Zieger
Claire Trenham
Brian Hally
Blake Seers*
Claire Spillman
Ron Hoeke
Emilio Echevarria
Vanessa Hernaman

I would like to begin by acknowledging the Traditional Owners of the Land and Sea Countries represented in this talk and dataset, and pay my respect to their Elders past and present.

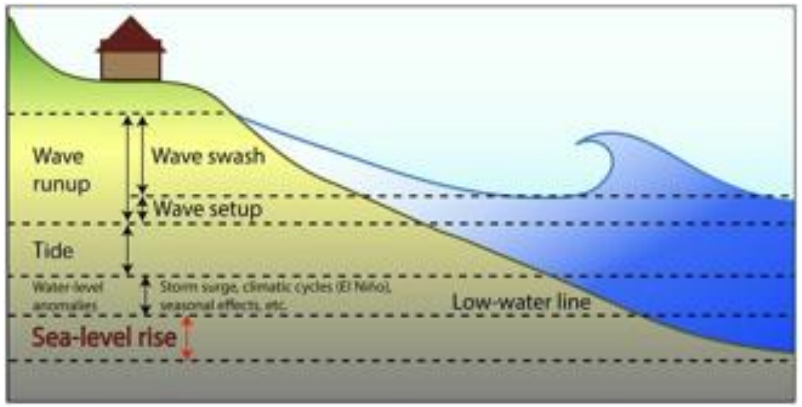
'Eternal Wisdom, Infinite Innovation'
artwork by Rachael Sarra, working with Gilimbaa.

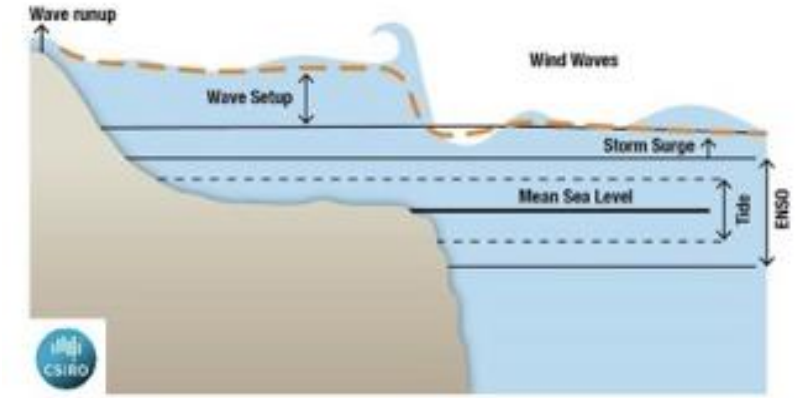
The Critical Role of Waves in Coastal Extremes and Shoreline Change

Coastal erosion and sediment transport – need to understand how **wave height**, **period** and **direction** are changing and how this could affect the Australian coastlines,

Flooding and storm surge – waves can contribute to coastal flooding and **breach coastal defences**.

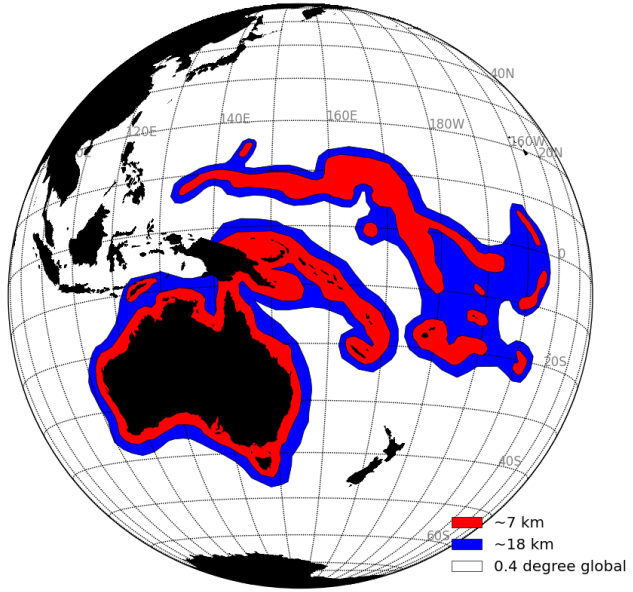
Coastal structures and infrastructure – wave height, period and direction is essential for resilient coastal structure and infrastructures,





WHACS: A replacement for the CAWCR Wave Hindcast

- The CAWCR Wave Hindcast (http://hdl.handle.net/102.100.100/137152) was created in 2011
- Uses a previous version of WaveWatchIII - the physics no longer considered the best available
- Forced with CFSR/CFSv2 winds, pressure and sea ice - this reanalysis is no longer the best available
- High-res only in certain coastal areas – poor resolution globally
- Variable names changed in 2014 when model version was changed
- Data is poorly chunked for reuse and timeseries analyses
- We desired:
  - Enhanced *global* coastal resolution
  - To upgrade model physics
  - To use ERA5 forcing data



Why WHACS?

- Generate **historical wave boundary conditions** for CSIRO's coupled wave-hydrodynamic model for extreme water levels (CCHaPS)
- **Align** model with the Bureau of Meteorology's operational forecast wave model **AUSWAVE-G3** by using the same physics and Spherical Multi-cell (SMC) grid.
- Provide **historical wave outputs** for existing customers and partner organizations (Defence, NIWA, Oil & Gas, Pacific)
- Serve as an **upgrade** of the existing wave CAWCR hindcast with the latest WaveWatch III version and **improved** global and regional **resolution**

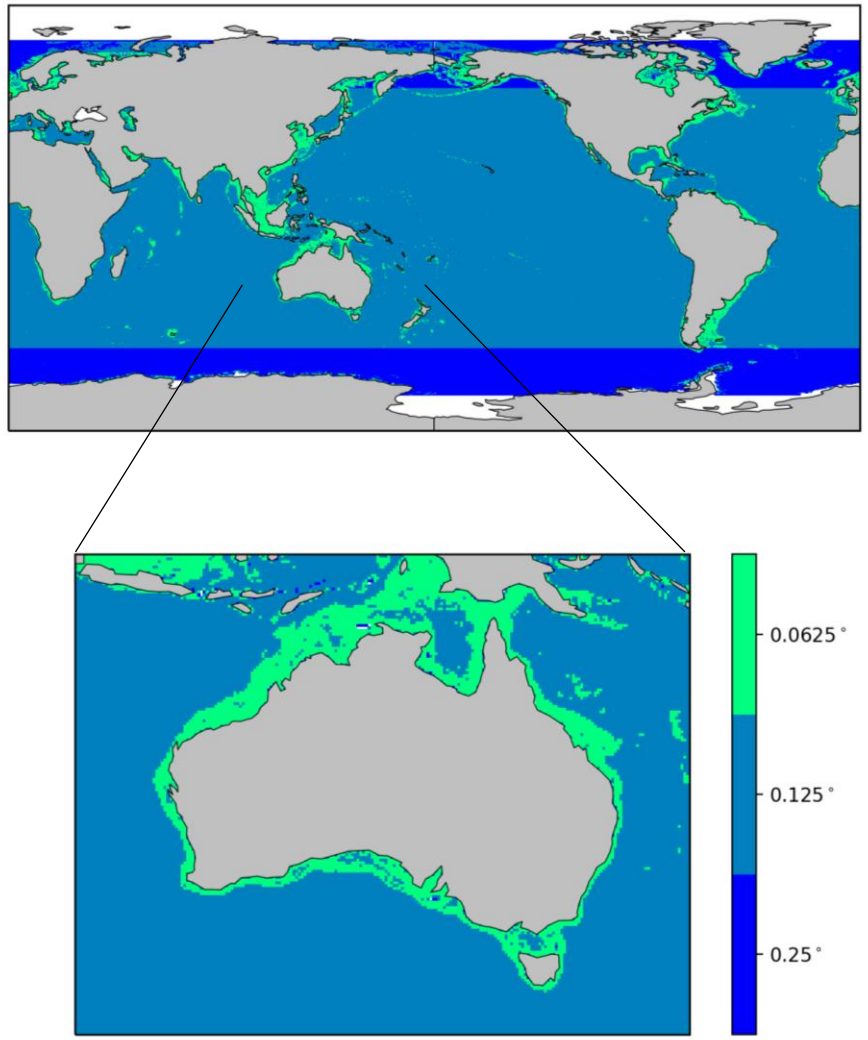
NOAA-EMC/**WW3**

WAVEWATCH III

The Wave Hindcast for the Australian Climate Service (WHACS) grid

Three layer "spherical multi-cell" (SMC) grid

I. 0.25° (~28km)
II. 0.125° (~14km)
III. 0.0625° (~7km)



Outputs 1-hourly

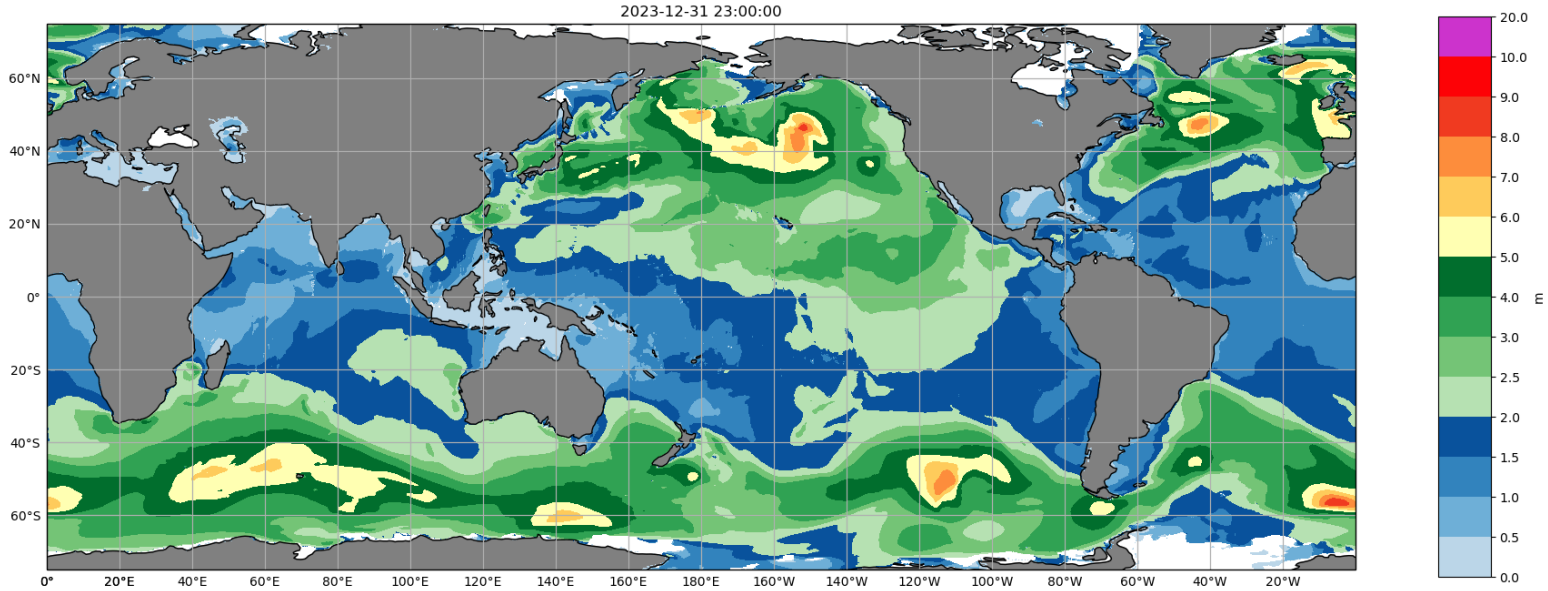
- on SMC grid
- re-gridded over a global 0.125° grid
- re-gridded over a 0.0625° reg. grid around Australia

WHACS: Output Types

- Bulk wave parameters at every grid point, both SMC grid and regridded rectilinear grids
- Spectral wave output at >11k select locations and geographic regions
- WaveWatch III format boundary conditions
- Accommodate for a wide range of users (Defence, Pacific, NIWA)

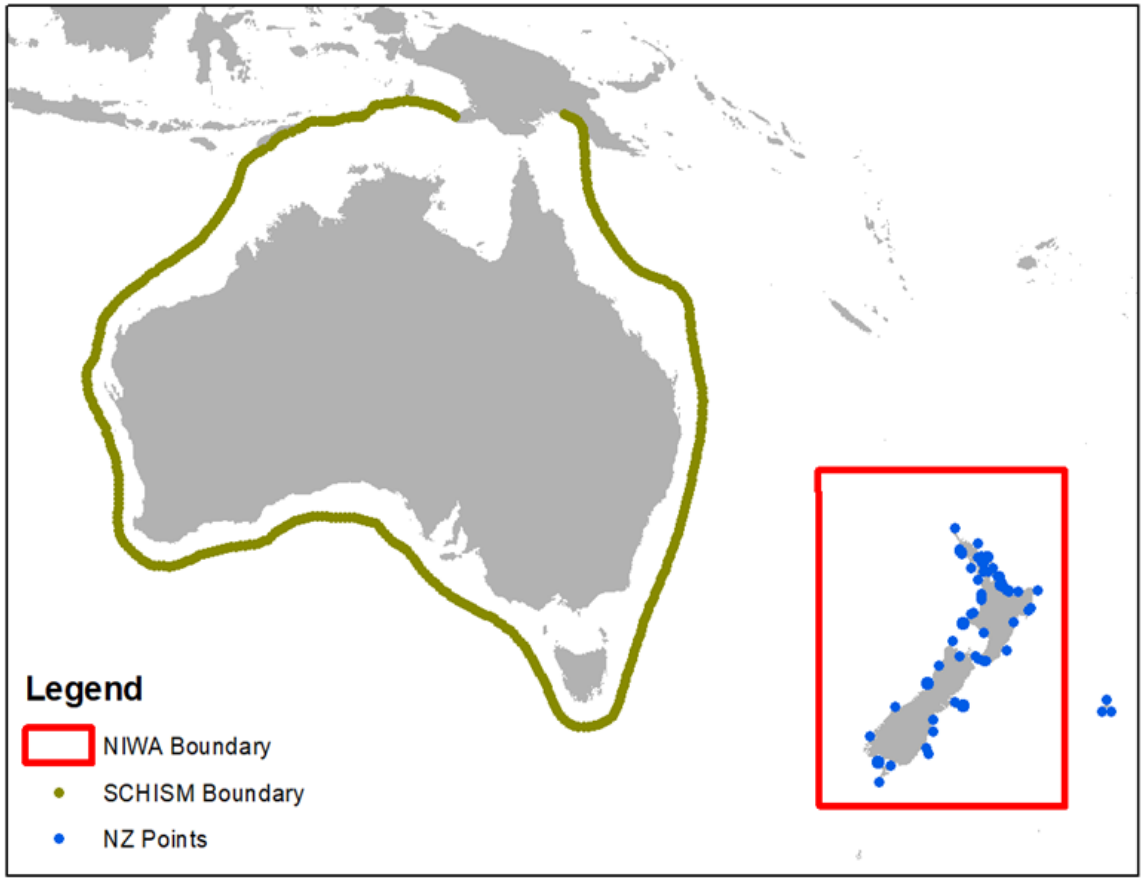
Applications:

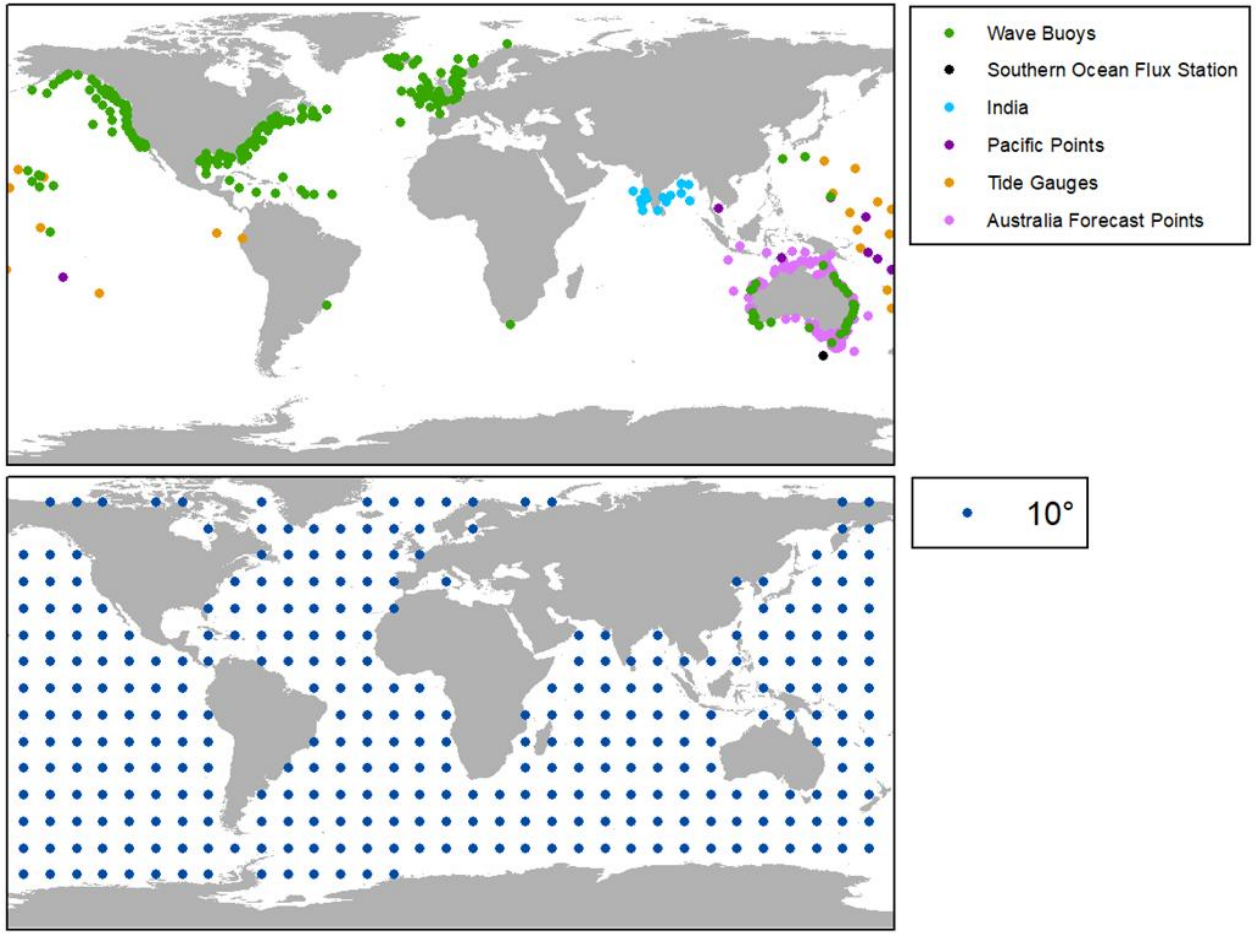
- Pacific modelling of coastal hazards
- Wave climatology & statistics
- Renewable energy assessments
- Boundary conditions for many downscaling projects
- Near Real Time Verification of operational forecast model
- Put events into context (extreme value analysis)



Spectral Output Point Locations

These points can be used to force regional models

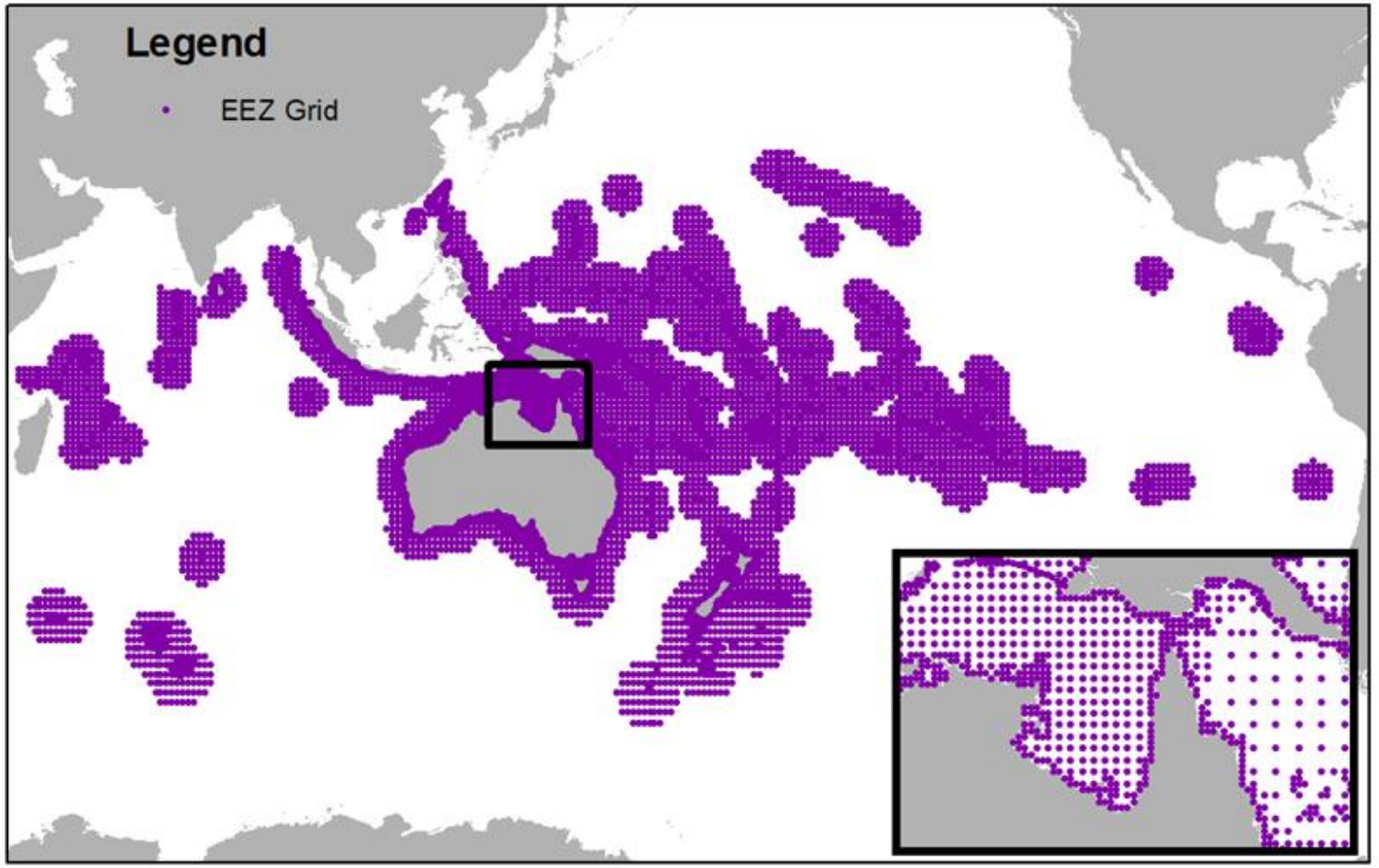




Spectral Output Point Locations

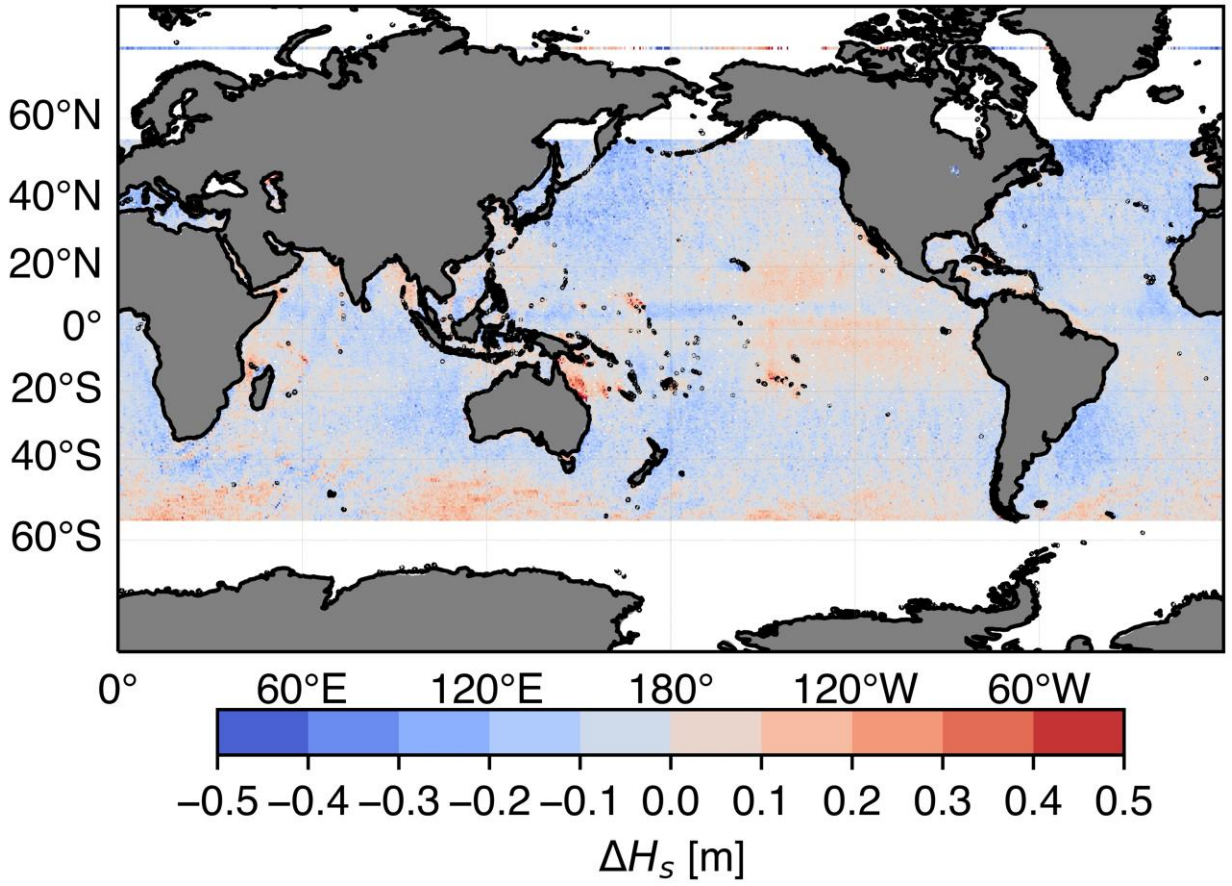
Primarily for creating spectral boundaries for downscaling:

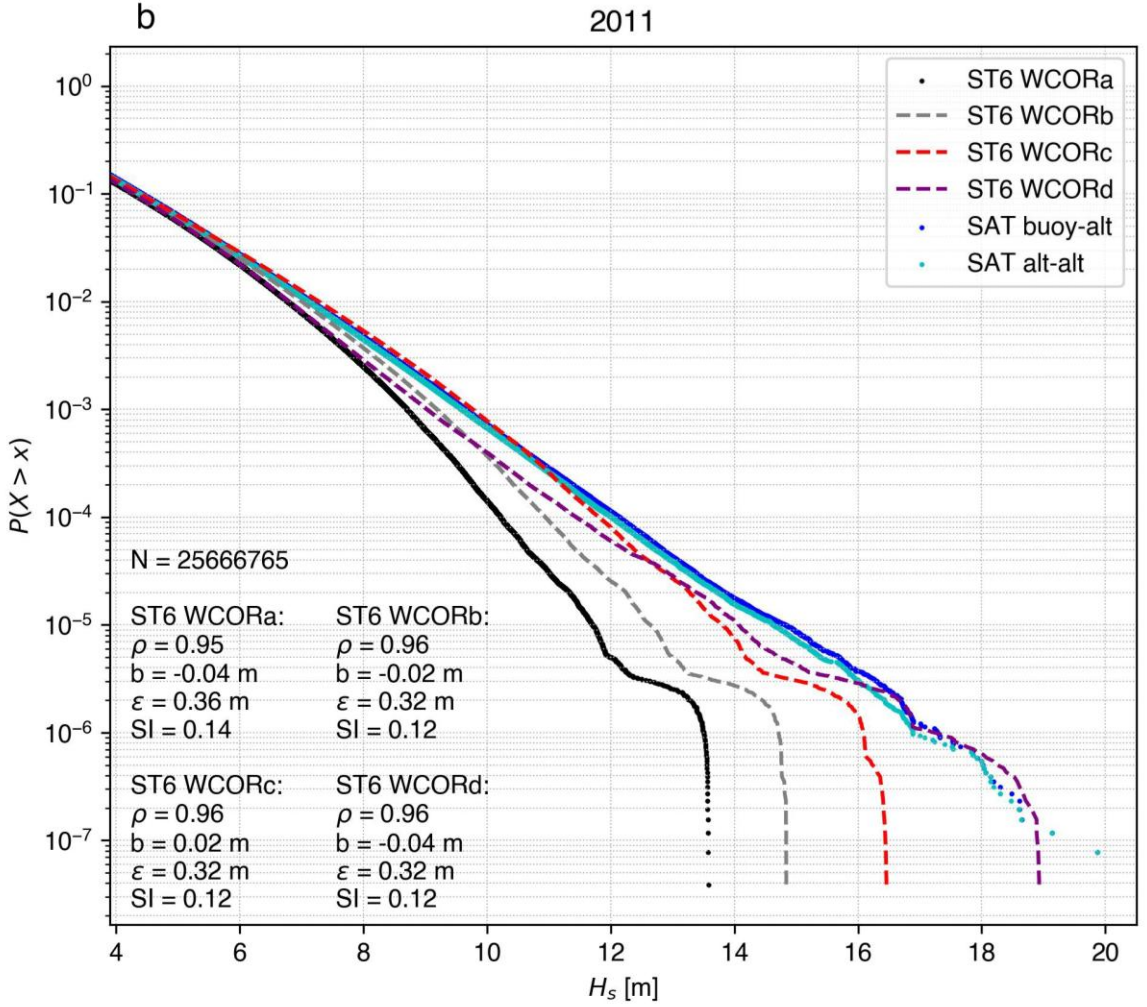
- 1 degree spacing for selected EEZ in Pacific and Indian Ocean
- 30 min spacing for depths shallower than -500m
- 15 min spacing within 25 km of major land masses (larger than 1km^2)



Wind Calibration against AODN satellite altimeter

25+ million wave model/altimeter collocations at 1/8-degree res.

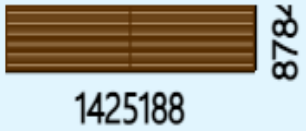




Getting the data analysis ready

Raw model output

	Array	Chunk
Bytes	46.64 GiB	2.72 MiB
Shape	(8784, 1425188)	(1, 712594)
Dask graph	17568 chunks in 28 graph layers	
Data type	float32 numpy.ndarray	



Optimised

	Array	Chunk
Bytes	46.64 GiB	28.12 MiB
Shape	(8784, 1425188)	(1464, 5036)
Dask graph	1698 chunks in 2 graph layers	
Data type	float32 numpy.ndarray	

Workflow

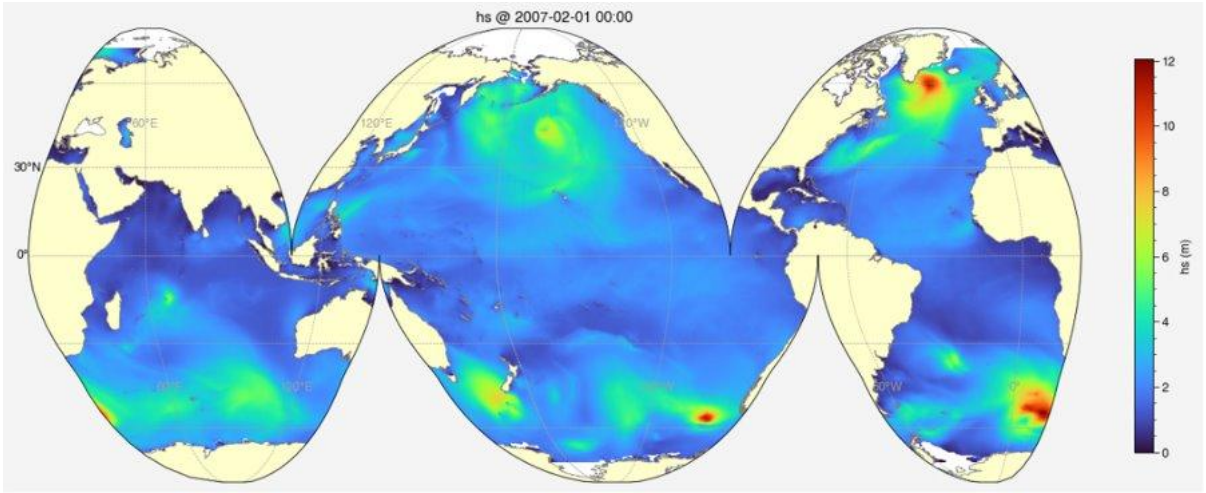
Choose	Choose chunk size – balance time/space points so each chunk is between 10--100MB
Create	Create Zarrs – 1 per model year, write to /scratch for intermediate, analysis-ready data
Convert	Convert back to netCDF – modify metadata and optimize data encoding
Check	Ensure standards compliance (CF, ACDD, UGRID)
Copy	Copy from NCI to CSIRO storage for publication – retain the optimized netCDFs on NCI
Publish	Publish via DAP – S3 storage, adjacent to CAWCR and other wave data, available via TDS (FAIR data)

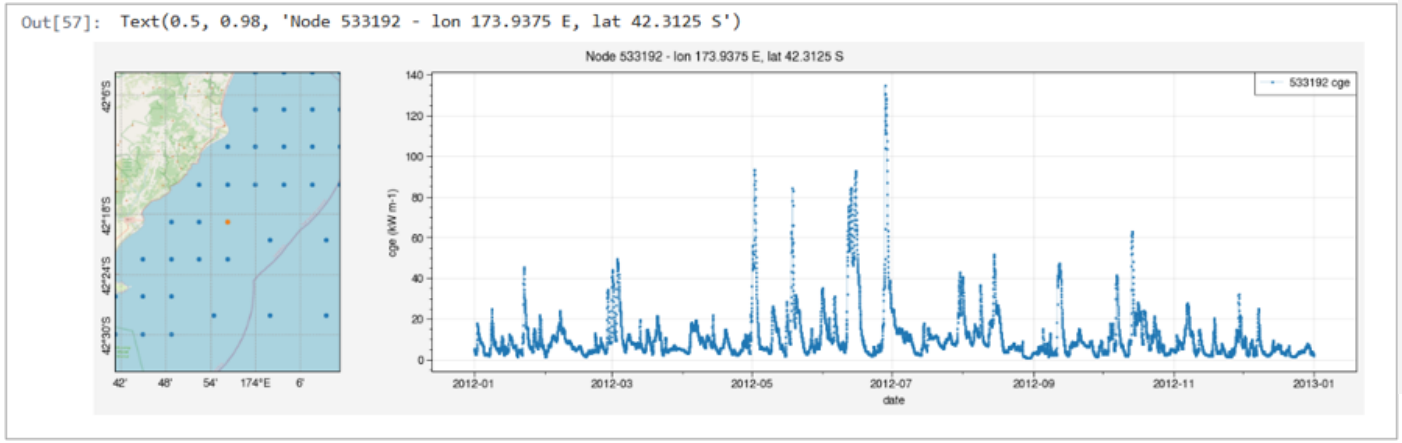
Improved data performance and usability

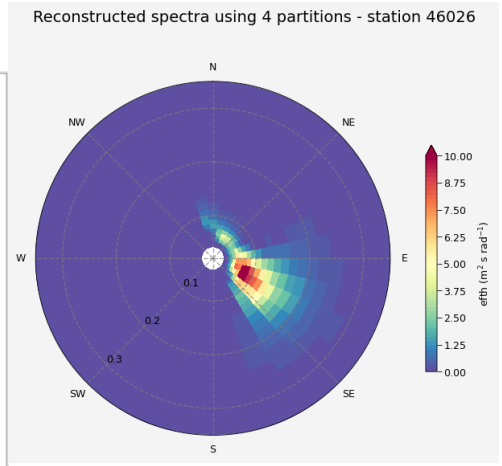
- Re-ordered the points to group them spatially within the files.
- Compliant with all relevant metadata standards.
- Rechunked to optimize performance for both timeseries and spatial analyses (compromised).
- Data recast from float64 to int16, with scale and offset values to minimize required disk space.
- Internal file compression to further minimize disk space.
- Data is made available for direct download from CSIRO's Data Access Portal or via THREDDS.
- A notebook demonstrating data use is supplied with the dataset.

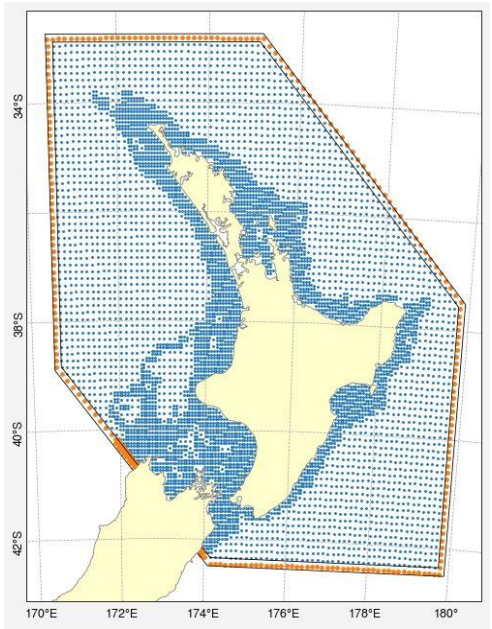
Example Jupyter Notebook

- Programmatically connect to the Thredds server.
- Navigate the directories and various data files.
- Demonstrate common usage, including:
  - Static maps (and unconventional projections!)
  - Extract a time series
  - Plot node locations on a map
  - Extract boundary nodes
  - Working with and plotting the spectral data





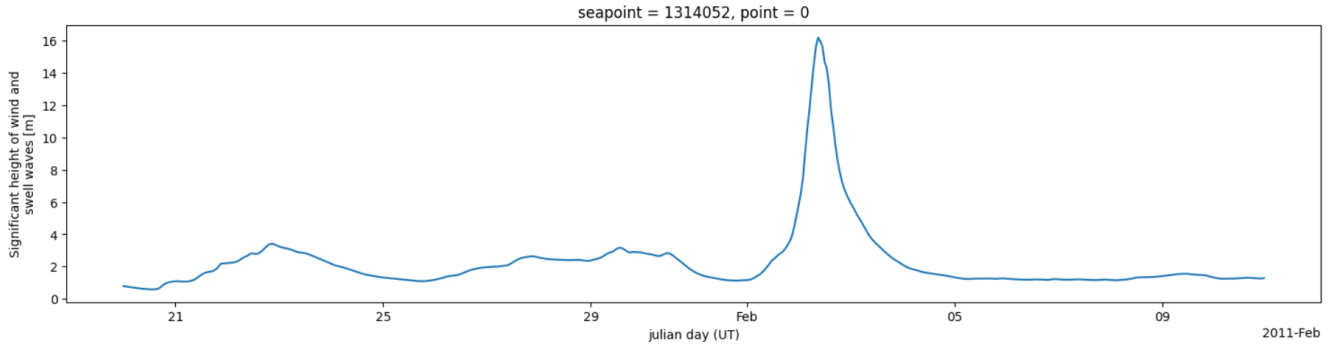




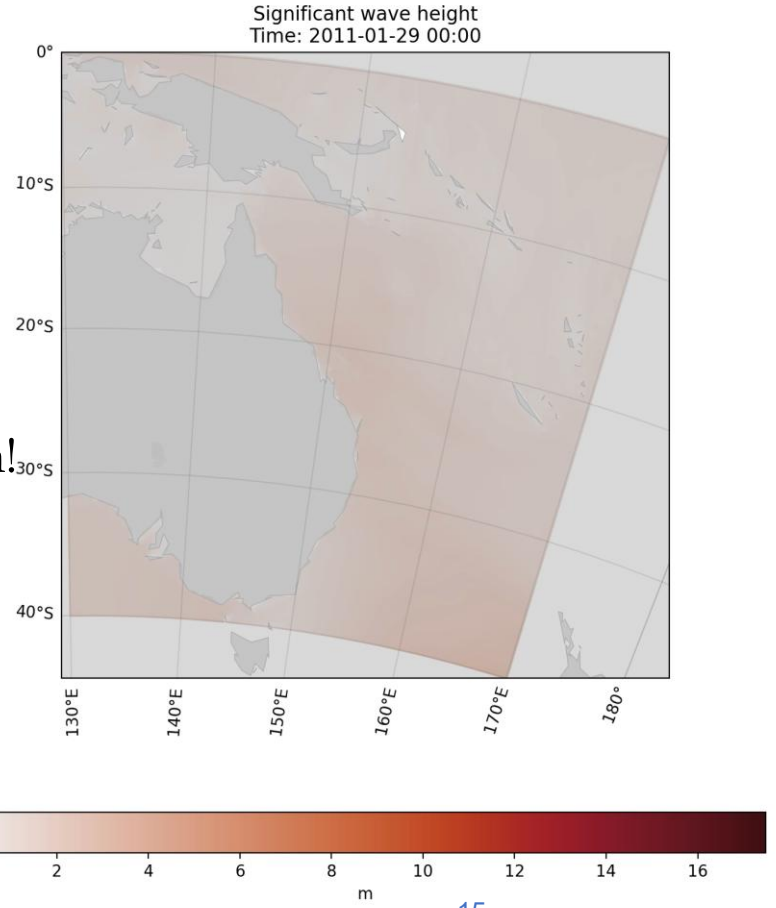
EMSArray works with WHACS

- EMSArray is an open-source Python package
- Simplifies working with (compliant!) gridded data
- It understands the grid topology (including SMC!)
- Easily generate plots and animations
- Select points at the nearest node(s)
- See poster #22 (Tim Heap)
- See poster #7 (David Secretan-Hallett) for a dashboard implementation!

```
point_extraction.extract_points(whacs_ds.sel(time=slice('2011-01-20', '2011-02-10')), [Point(147.3, -18.2)])['hs'].plot()
```



Tropical Cyclone Yasi



WHACS Key Takeaways

- New data product!
- Enhanced extreme wind calibration.
- Superior wave model physics.
- Improved accuracy.
- Increased spectral outputs.
- Higher global coastlines resolution.
- Cutting-edge spectral reconstruction.
- Post-processed to ensure efficiency and usability.
- Published alongside Python code.

Thank you for listening!

- Please feel free to use and cite our data!
  https://doi.org/10.25919/yp77-v026

- If you have any questions, please contact
  Grant Smith (Grant.Smith@bom.gov.au),
  Claire Trenham (Claire.Trenham@csiro.au)
  Alberto Meucci (Alberto.Meucci@unimelb.edu.au)
  Blake Seers (Blake.Seers@csiro.au)