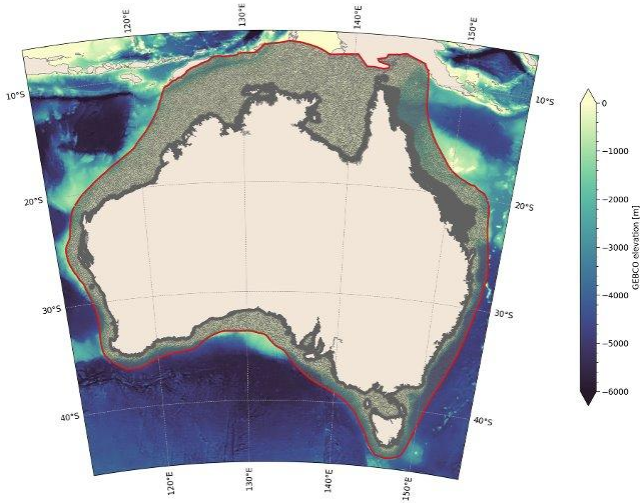


Coastal Ocean Extremes: the Australian Climate Service (ACS) Coupled hydrodynamic-wave Coastal Hazard Prediction System (CCHaPS):

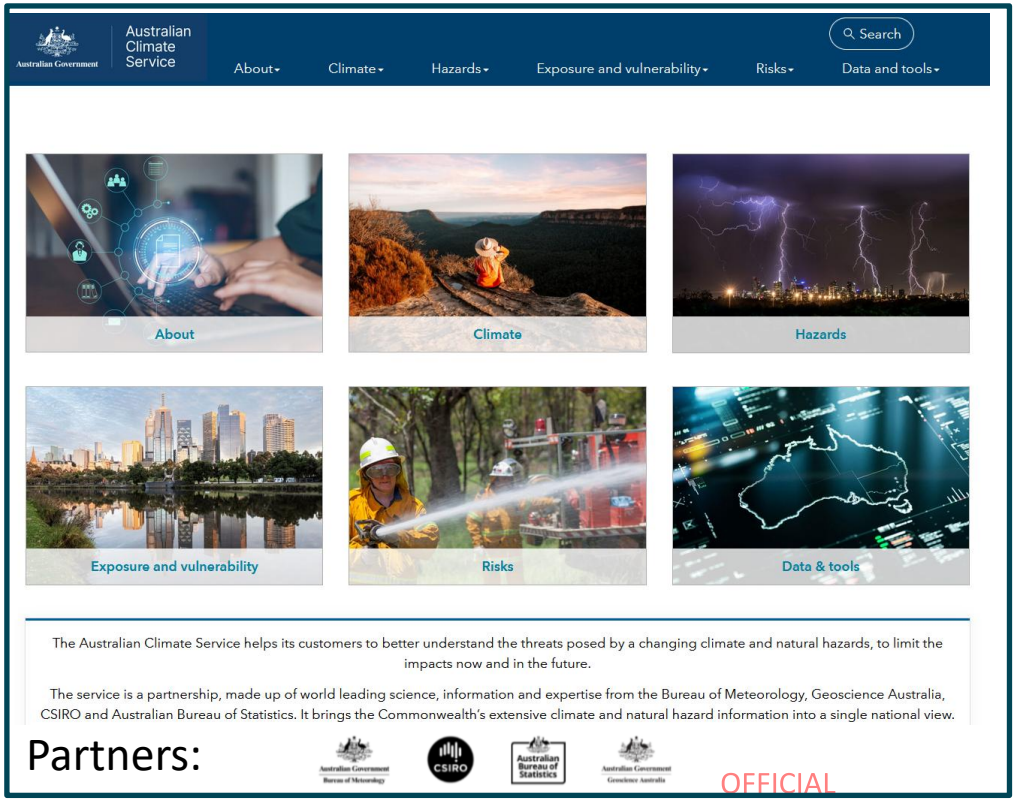
Hindcast and Climate Projections

Vanessa Hernaman, CSIRO

Bryan Hally, Alberto Meucci, Claire Trenham, Ron Hoeke, Julian O'Grady, Kathy McInnes, Xuebin Zhang, Blake Seers, Emilio Echevarria, Richard Matear

Australian Climate Service (ACS) (2022-2025)

Aim: provide improved data, intelligence and expert advice to "better understand threats posed by natural hazards and a changing climate, to limit impacts now and in the future"

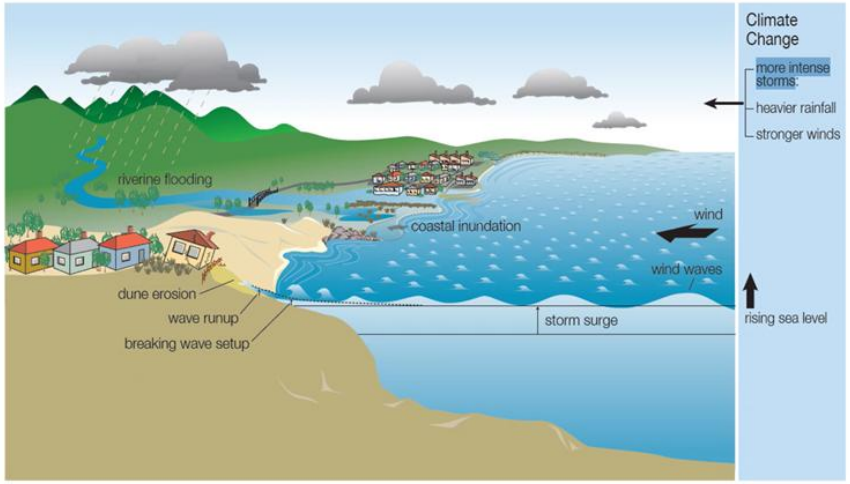


Partners:

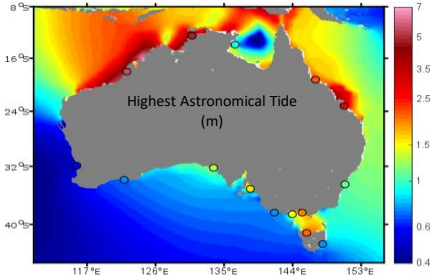
Coastal hazards: provide detailed ocean extremes data, analyses, and products to inform present and projected future coastal hazard assessment for all of Australia in a nationally consistent manner

https://www.acs.gov.au/

Australian Climate Service: national coastal extremes

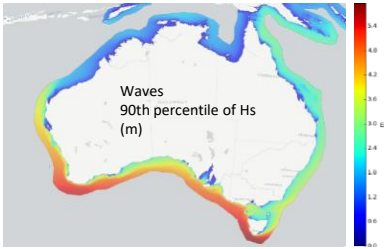


- Sea-level rise
- Tides
- Storm surges
- Waves
- Non-linear interactions of the above processes
- Seasonal factors
- Interannual factors
- Climate change factors



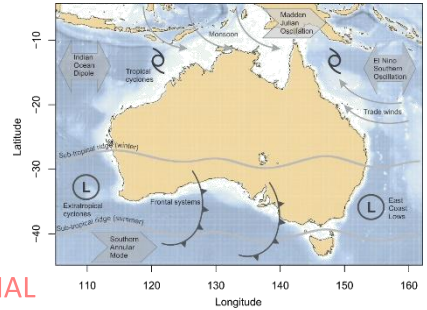
Source: McInnes et al, (2016)

Tidal range highest in the north of the continent



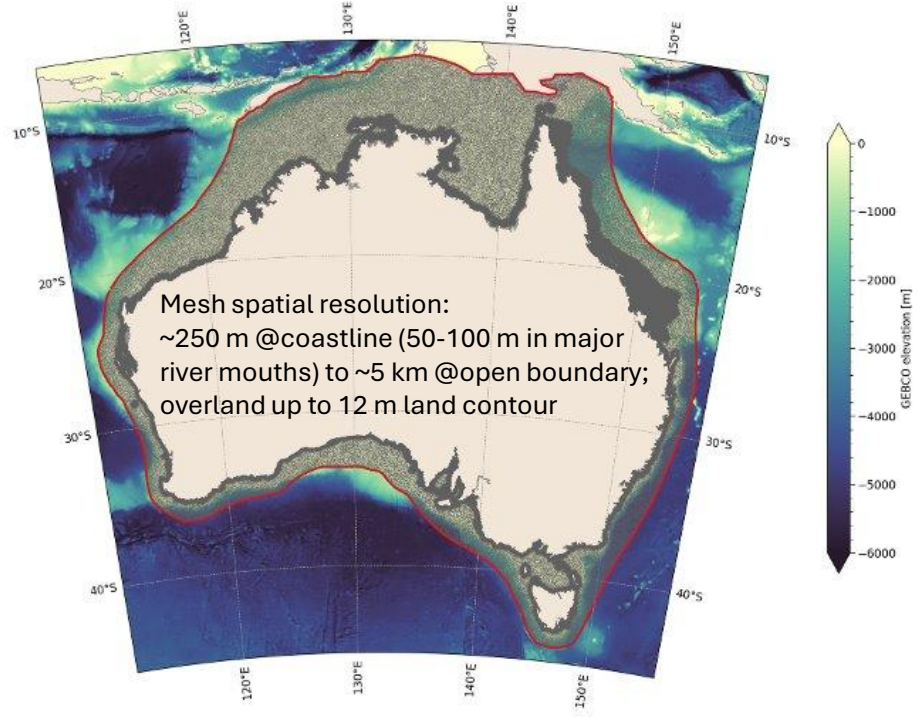
Source: Wave Energy Atlas
http://nationalmap.gov.au/renewables/

Wave heights largest on the southwest and southern coasts

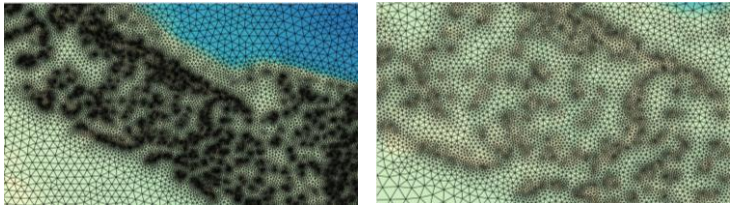


Geographical variation in meteorological & climate drivers of coastal extremes that are influenced in a variety of ways by climate change

National Coupled hydrodynamics-wave Coastal Hazard Prediction System (CCHaPS)



~500+ m over GBR



The ACS national CCHaPS implementation dynamically includes all of the following:

- Sea level
- Astronomical tide
- Storm surge
- Wind waves
- Historic hindcast
- Future climate projections

Features:

- Coupled hydrodynamic-wave model
- Includes wetting/drying
- High-resolution unstructured mesh extending overland
- Captures key nearshore processes (incl. non-linear wave-current effects, nearshore momentum flux, etc.)
- Utilises as forcing ACS atmospheric reanalyses and projections, wave hindcast and projections, etc.

Model forcing

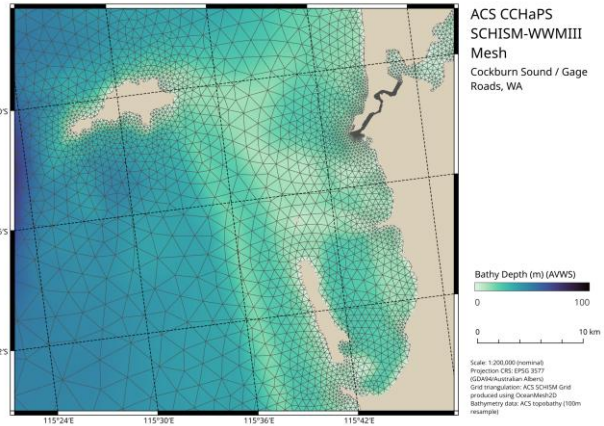
Model Forcing	Hindcast: 1981-2020 (-2024)	Projections: CMIP6-based time-slices (1995-2014; 2081-2100)
Atmosphere	BARRA-R2*	BARPA & CCAM CMIP6 downscaling* (ACCESS-CM2; EC-EARTH3; SSP3-7.0)
Sea Level	ECMWF ORAS5	AR6-based modified with regionalised SLR scenarios
Waves	WHACS*	COWCLiP high-res
Tides	TPXO9.2	

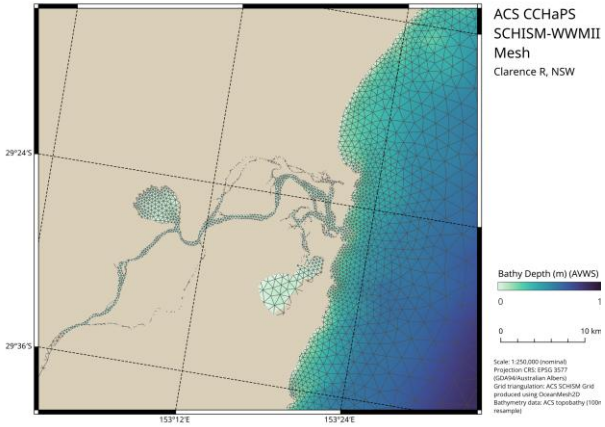
*delivered by other ACS Work Packages

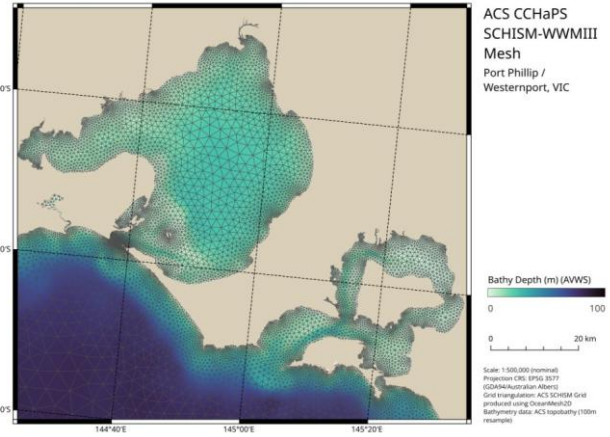
Bureau of Meteorology Atmospheric high-resolution Regional Reanalysis for Australia (BARRA)

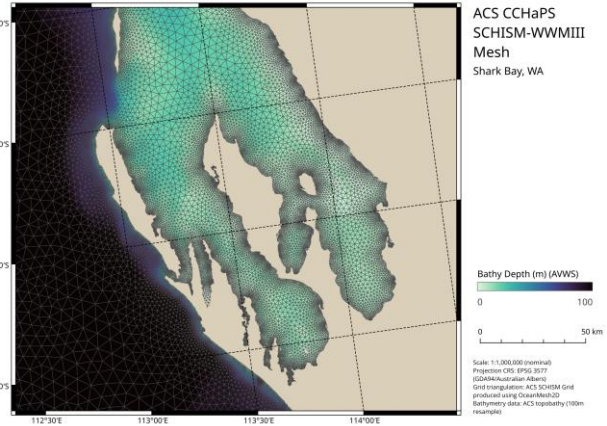
Conformal Cubic Atmospheric Model (CCAM)

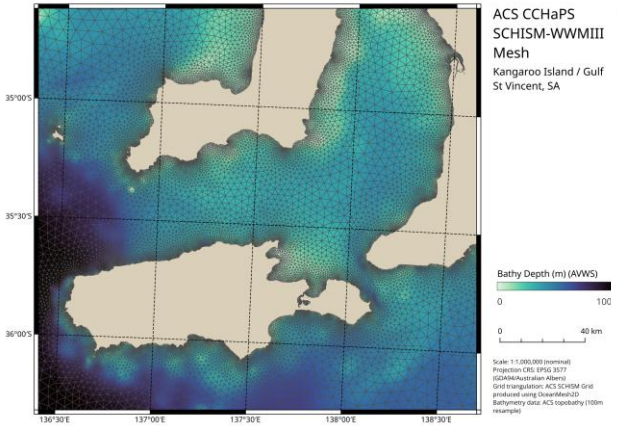
High resolution unstructured mesh

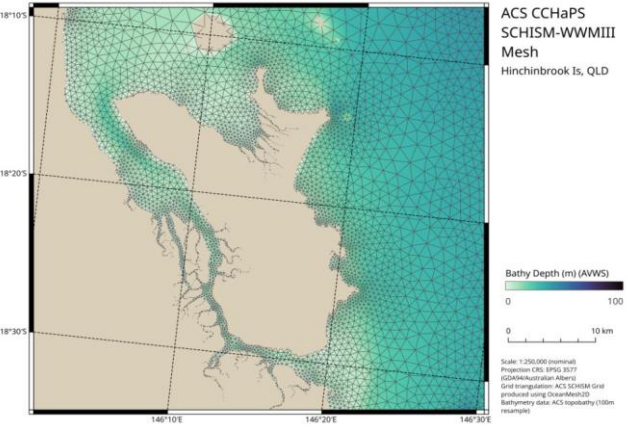






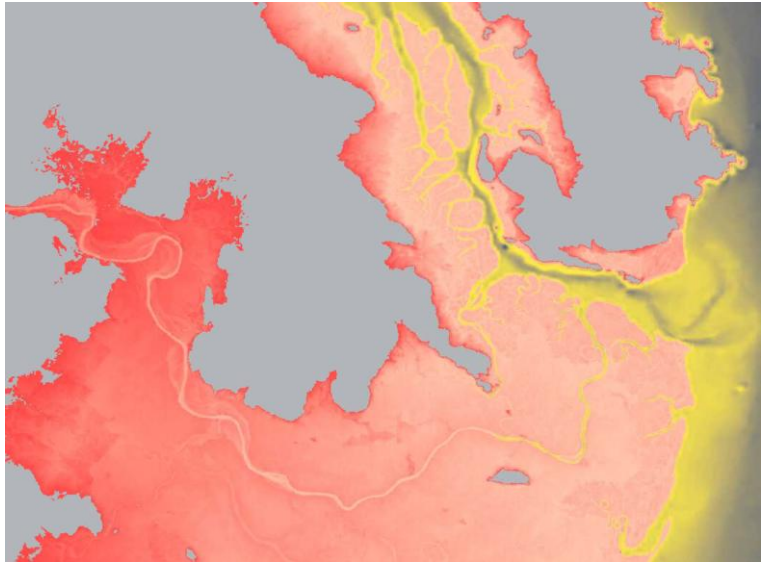




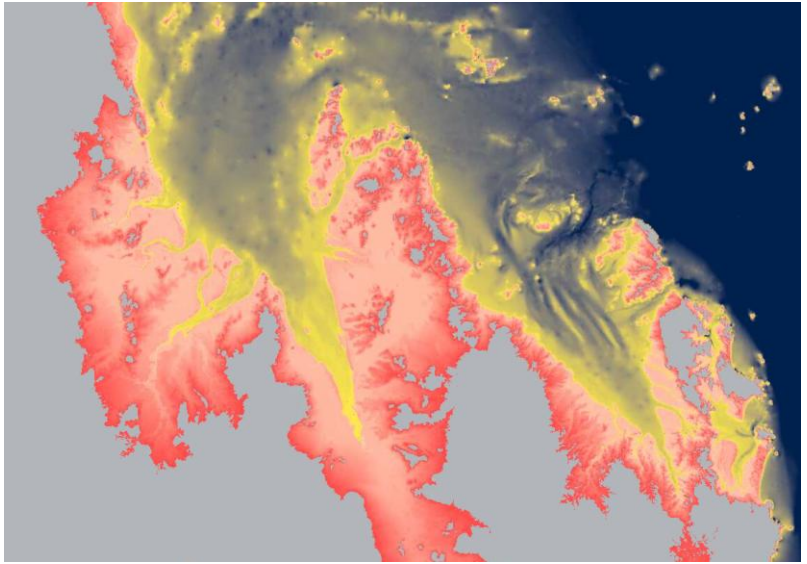


New topobathymetry

- High resolution datasets texture-mapped onto baseline data
- GLO-30 + GA250, with 183 high-resolution infill datasets
- Process smooths disjoints especially in bathymetric data
- Ensures data conformity to underlying baseline (Australian Vertical Working Surface; AVWS) datum



Lucinda/Hinchinbrook Island

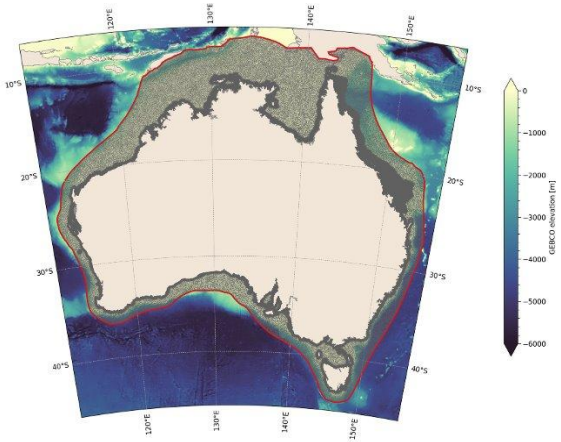


Herbert Creek/Broad Sound

Extensive validation

CCHaPS outputs hourly data at each of its 1.4 million nodes:

- Water levels (elevation)
- Depth-averaged current speed and direction
- Wave variables including:
  - Significant wave height (Hs)
  - Wave period (Tp) (mean and peak)
  - Wave direction (mean and peak)
  - Directional spreading
  - Orbital velocity

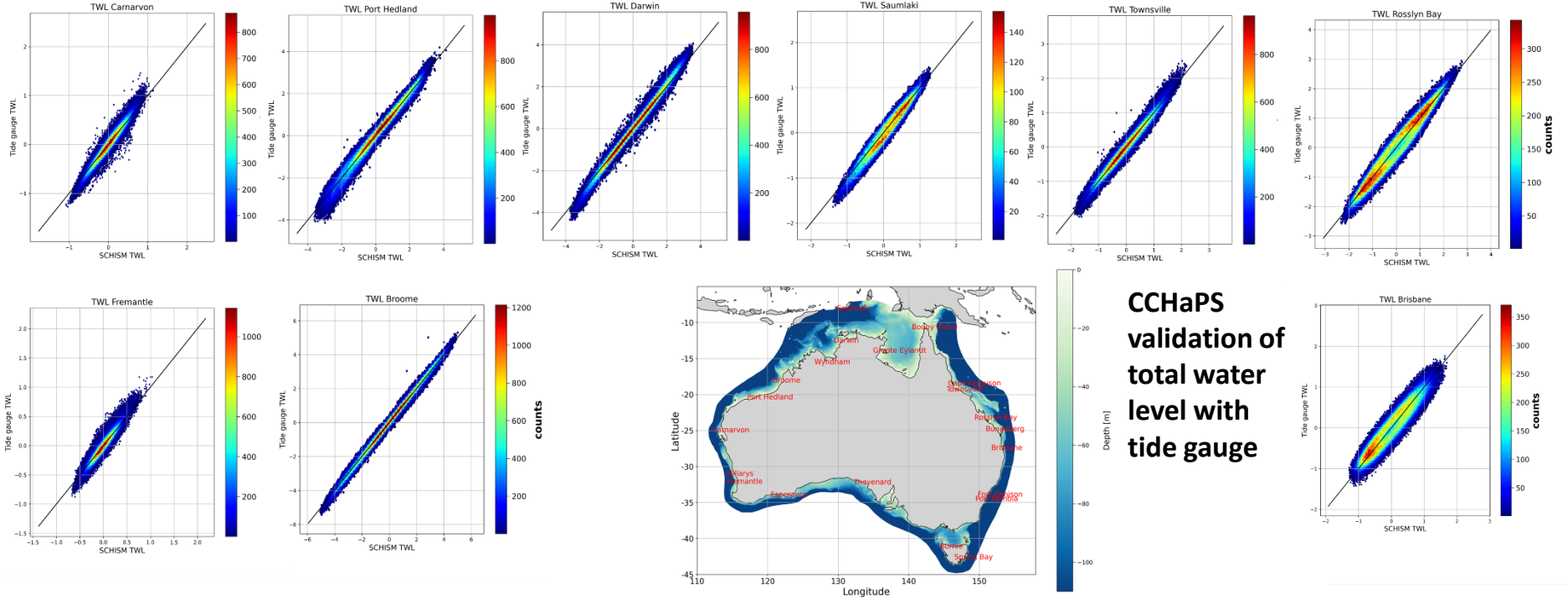


CCHaPS performing well in extensive validation of 40-year hindcast against suite of observation data

- Tide gauge (total water level, tidal component, storm surge, harmonic analysis)
- Acoustic Doppler Current Profilers (ADCP) (current magnitude and direction)
- Wave buoys (Hs, Tp, direction)
- Satellite altimeter (Hs)

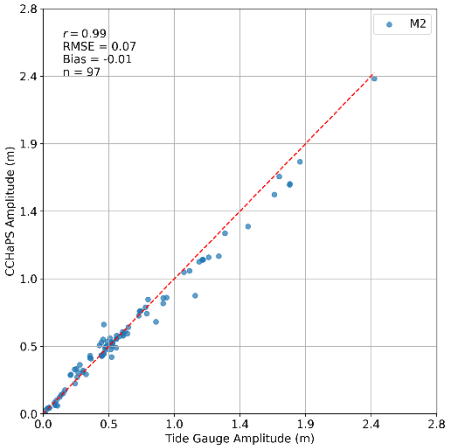
Spotter wave buoy (Geoff Gooley, CSIRO)

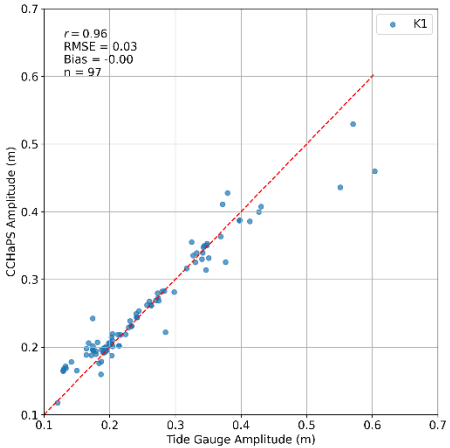
ADCP (www.whoi.edu)

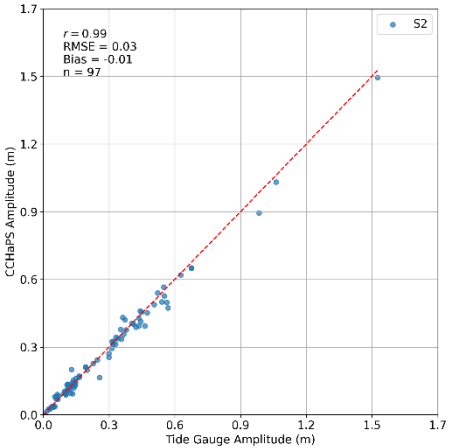


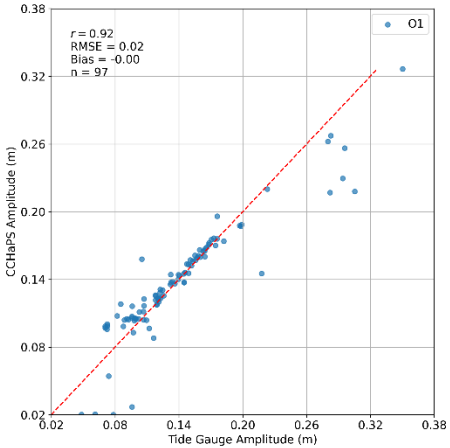
CCHaPS validation of total water level with tide gauge

Harmonic analyses – done for 97 gauges (68 constituents)

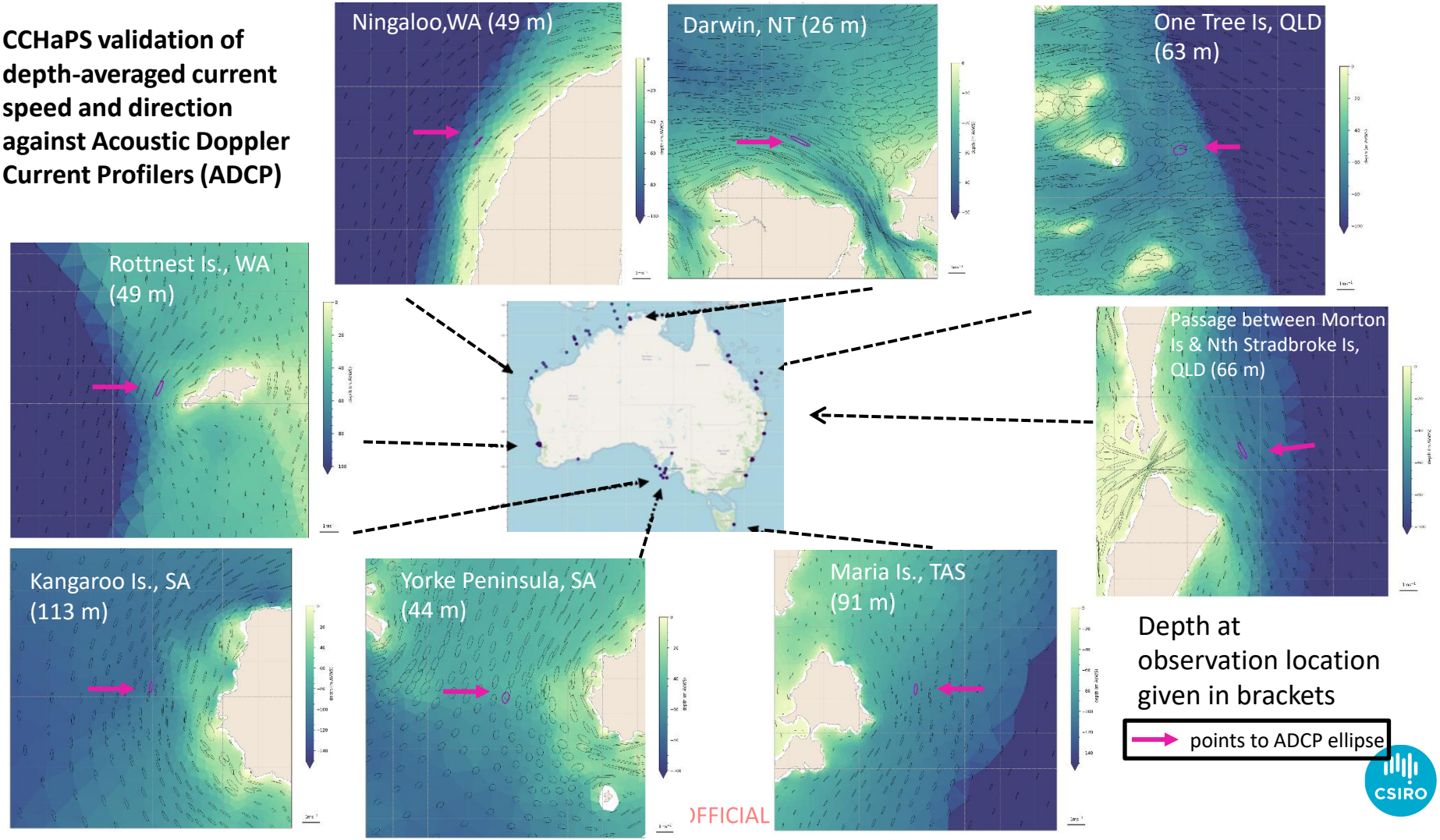




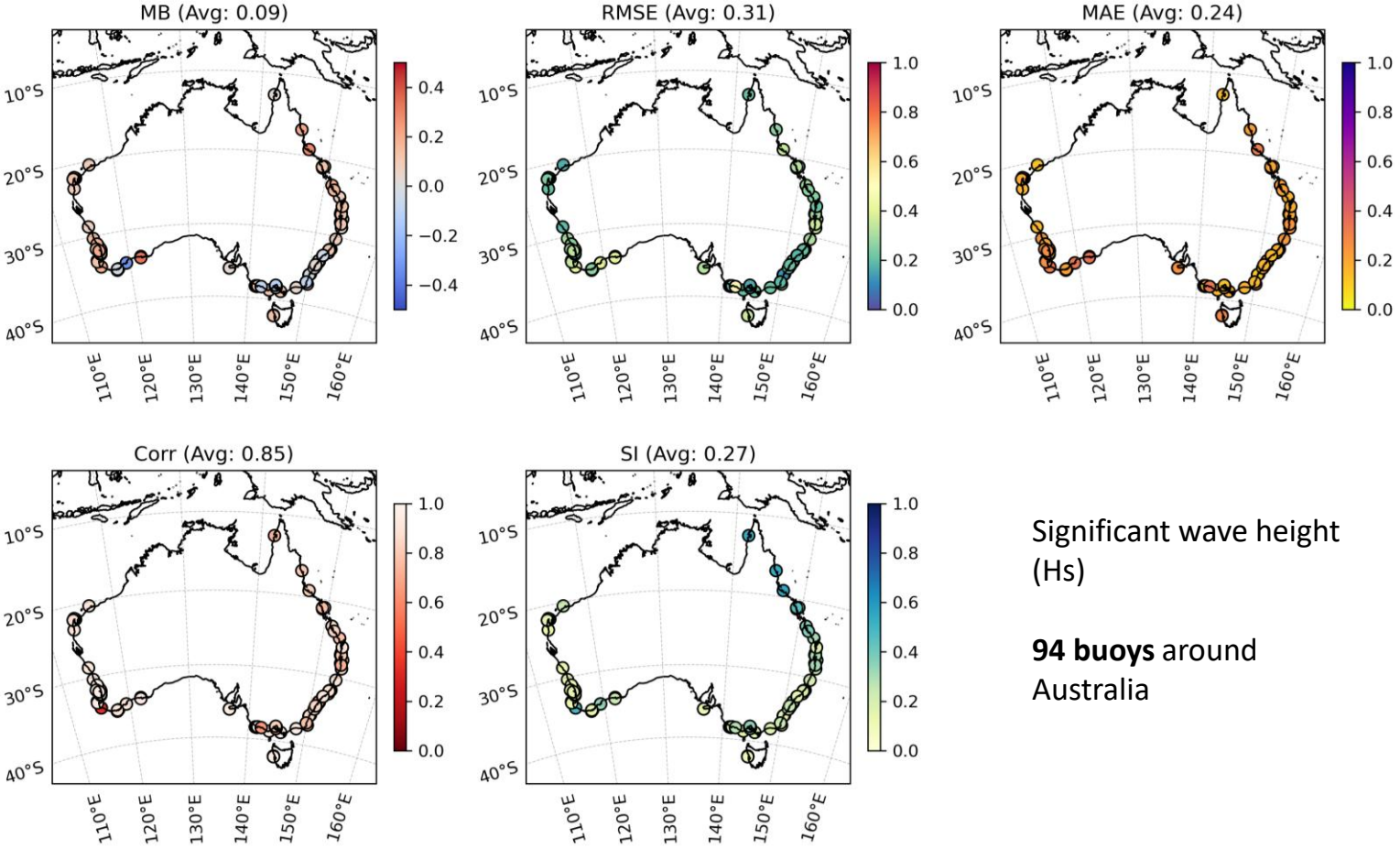




CCHaPS validation of depth-averaged current speed and direction against Acoustic Doppler Current Profilers (ADCP)



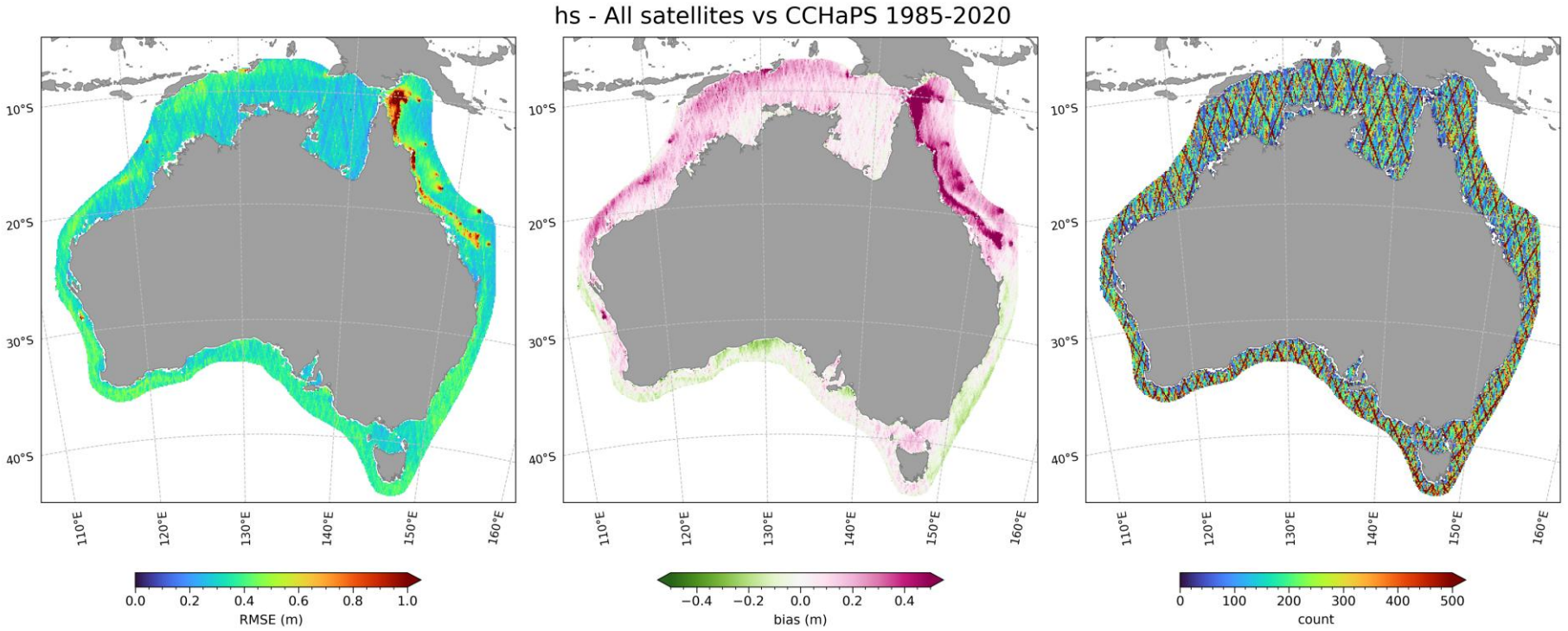
Wave buoy validation



Significant wave height (Hs)

94 buoys around Australia

CCHaPS validation wave heights and satellite altimeters



SCHISM-WWMIII output post-processing

The raw SCHISM-WWMIII output was post-processed to make it compliant with CF, ACDD and UGRID metadata conventions, and chunked for better performance.

- Disk space reduction to about 10% of the original value
- Compute tasks 2 to 3 orders of magnitude faster

(Contact our data guru, Claire Trenham, if you want to know more about it)

Claire.Trenham@csiro.au

Climate Projections

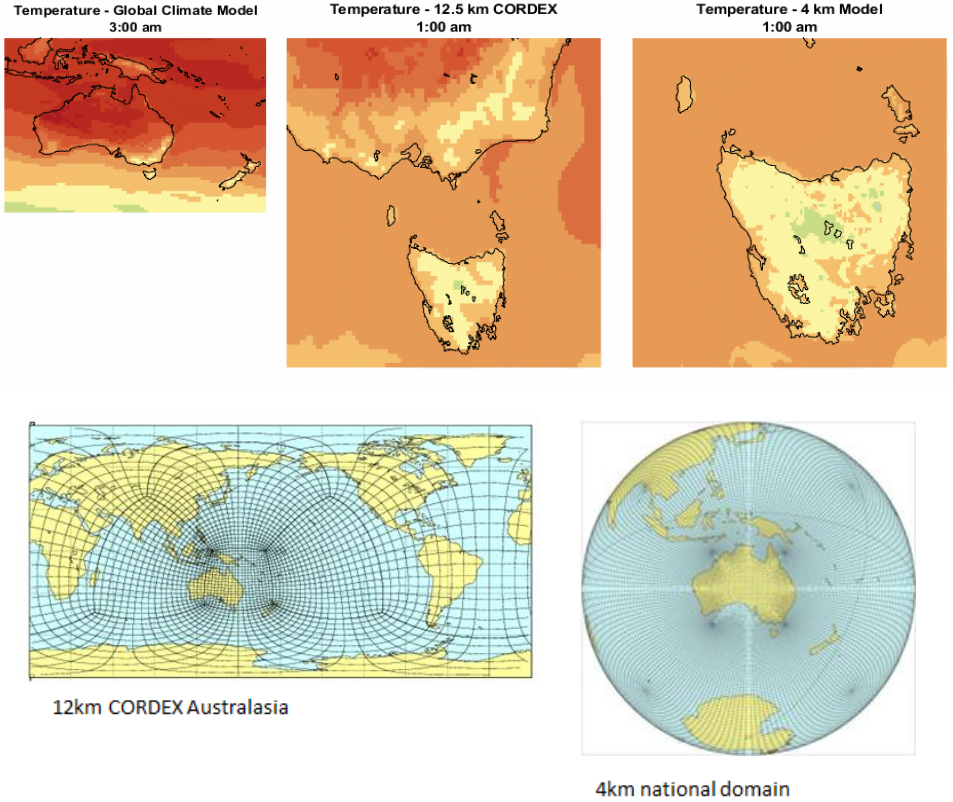
CCAM Modelling

Conformal Cubic Atmospheric Model (CCAM; CSIRO)

- Uses a stretched grid; avoids lateral boundaries
- Uses spectral nudging, constrains CCAM to follow large scale atmospheric weather patterns while still allowing it to respond to local forcing (e.g., land/sea temperature, frictional contrasts and topographic effects) when simulating local meteorological events and resolving smaller-scale features such as orographic wind, rainfall and land/sea breezes
- **12.5 km resolution** for CORDEX domain; also a 4 km resolution

Note added realism in the animation:

- Finer spatial and temporal resolution
- Effect of topography
- Diurnal cycle
- Land-ocean contrast, coastal effects



Marcus Thatcher, CSIRO

BARPA modelling

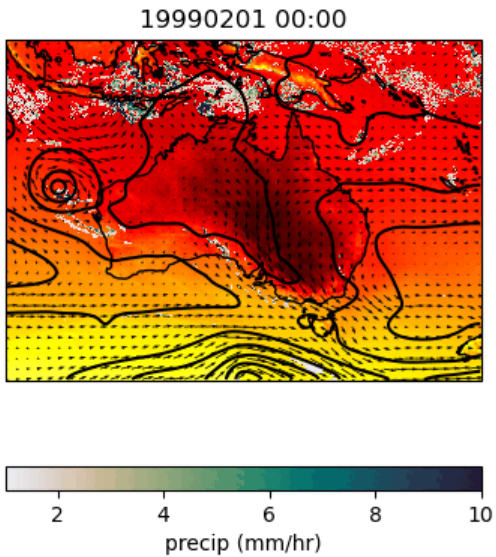
Left: BoM Atmospheric Regional Projections model for Australia (BARPA), developed by BoM based on the UK system

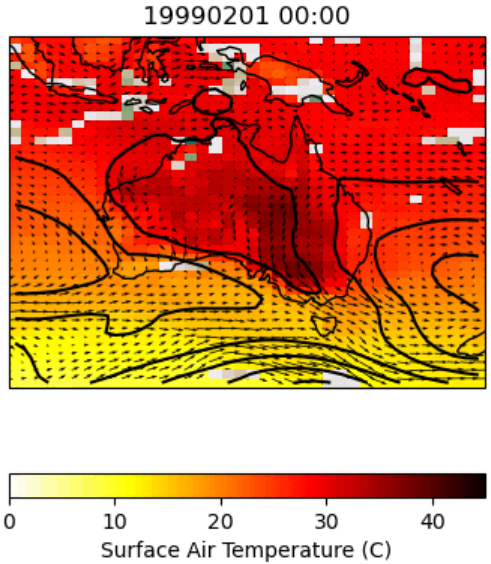
Right: Australia's global climate model (ACCESS-CM2) used as input

- Limited area model (LAM)
- ~12 km resolution

Note the added realism:

- Tropical low in NW
- Embedded storms
- Intense low to the east

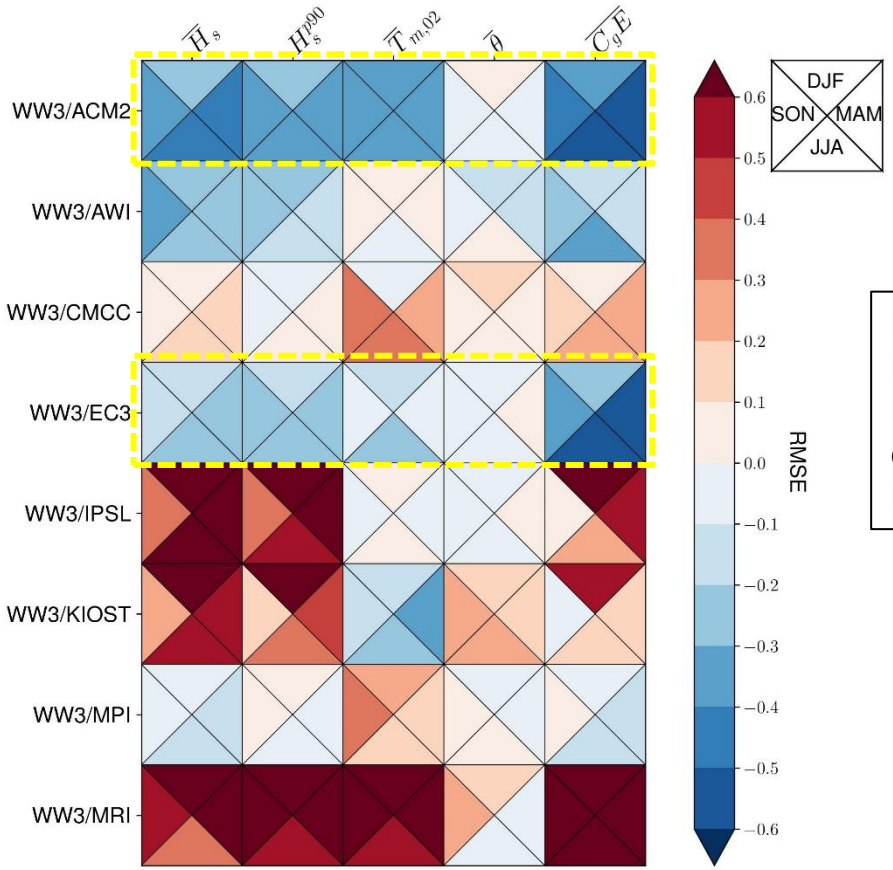




Chun-Hsu Su, BoM

Animation: Emma Howard

Projections: CCHaPS wave forcing
Alberto Meucci (UniMelb; CSIRO)



- both part of CORDEX downscaling ensemble endorsed by CSIRO and BoM
- their assessment of the climate around Australia identified these two models as among the best-performing for the region.
- Alberto's analysis showed these models also performed well globally in terms of wave climate.

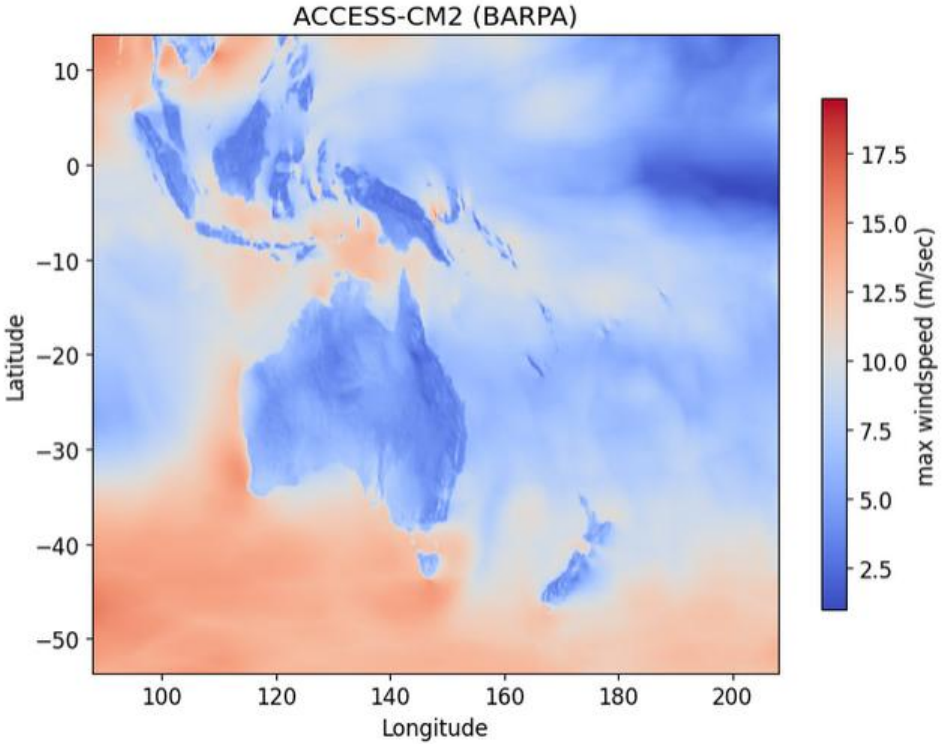
Each triangle (=season) inside box shows a global, normalised RMSE value.
RMSE negative: model performs better than median of ensemble
RMSE positive: model performs worse than median of ensemble

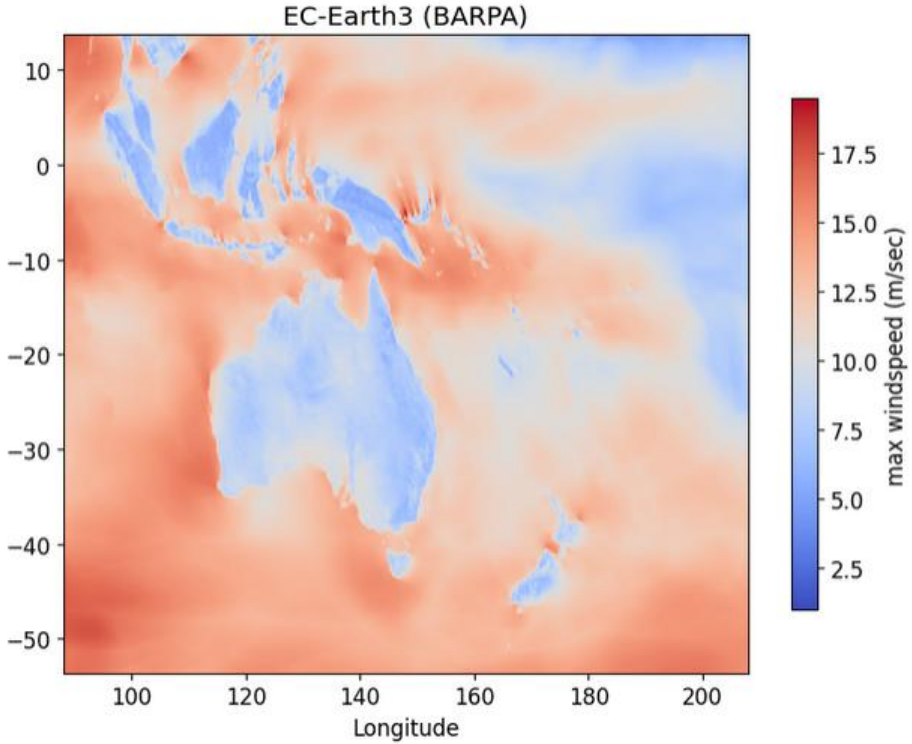
Spectral wave forcing on CCHaPS boundary from Alberto's WaveWatch3 model forced by BARPA- and CCAM-downscaled ACCESS-CM2 and EC-Earth3 atmosphere

Ensured consistency with atmospheric forcing used directly by CCHaPS

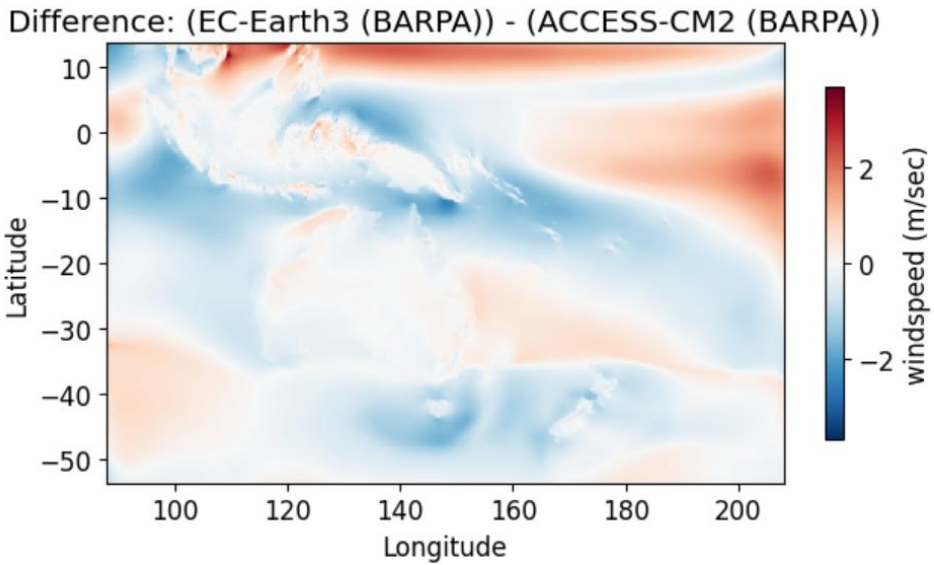
GCM differences in max windspeed

Max windspeed (m/sec) – 2081-2100

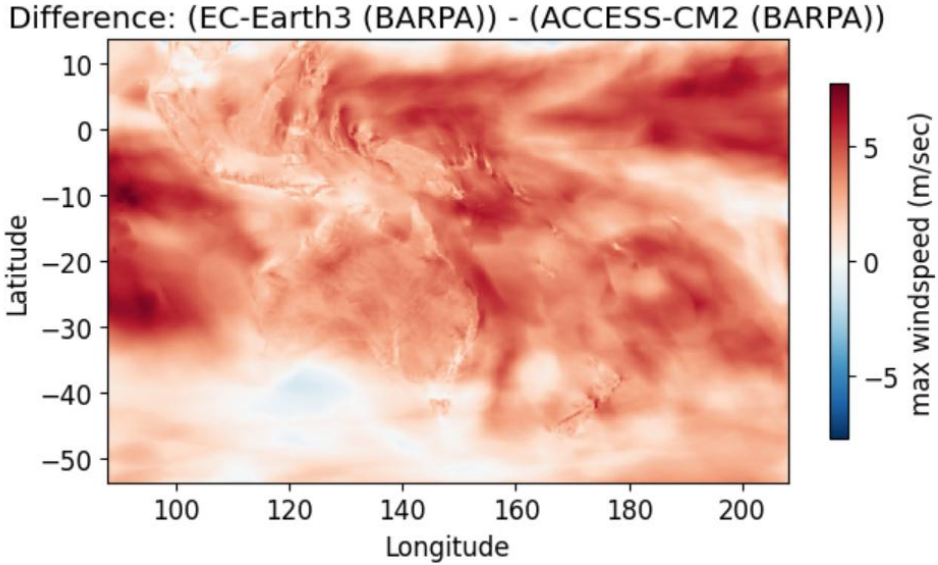




Difference in 20-year mean (2081-2100)



Difference in 20-year max (2081-2100)

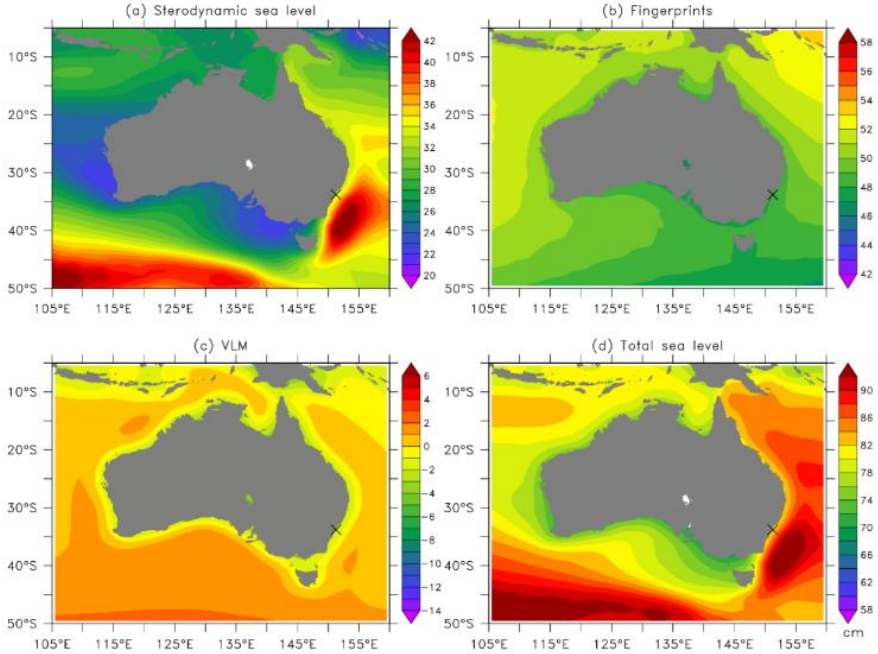


Ongoing analyses of downscaled-GCMs differences in wind and MSLP characteristics monthly, seasonally, variability, extremes, etc.

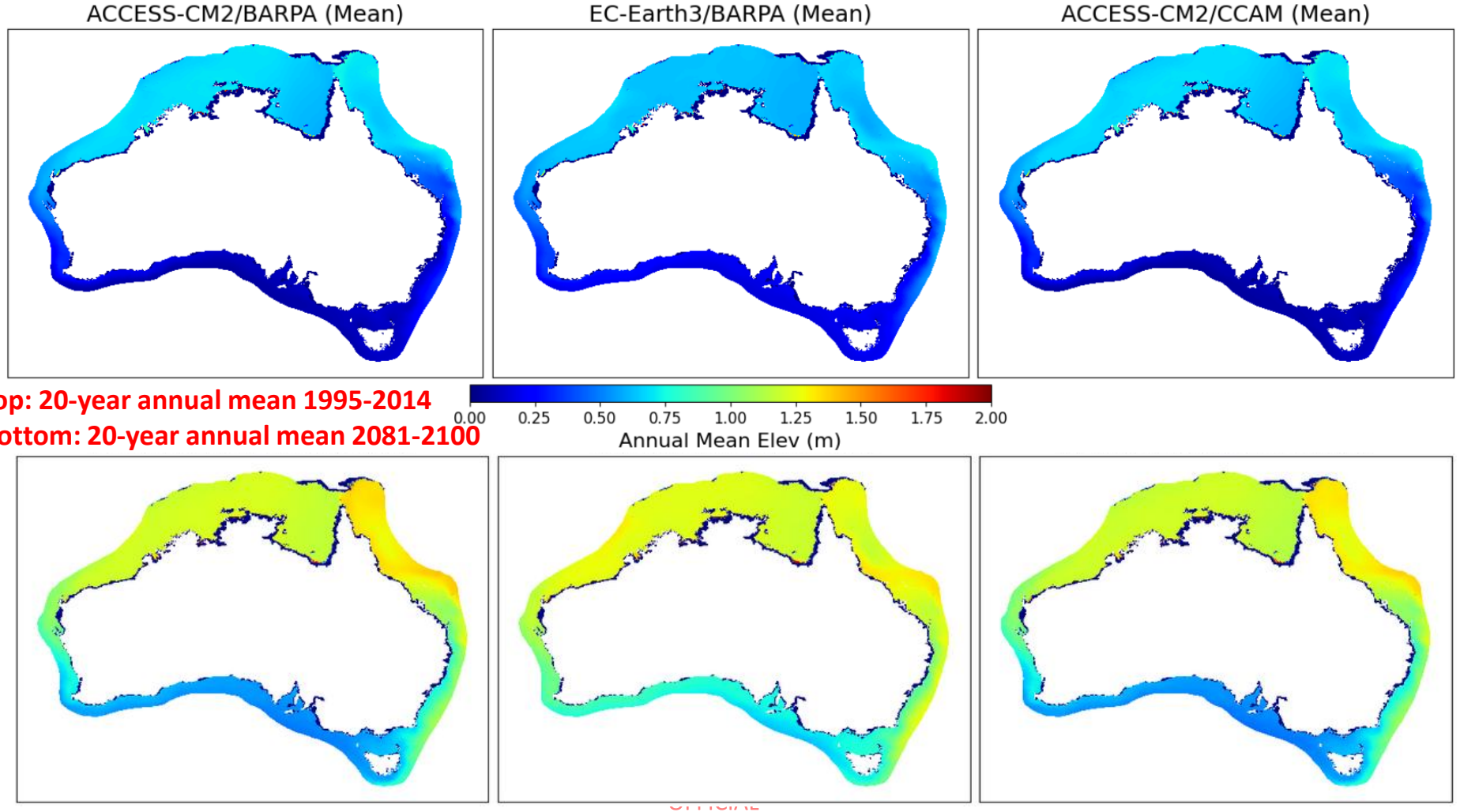
Regionalised CMIP6 SLR projections (Xuebin Zhang)

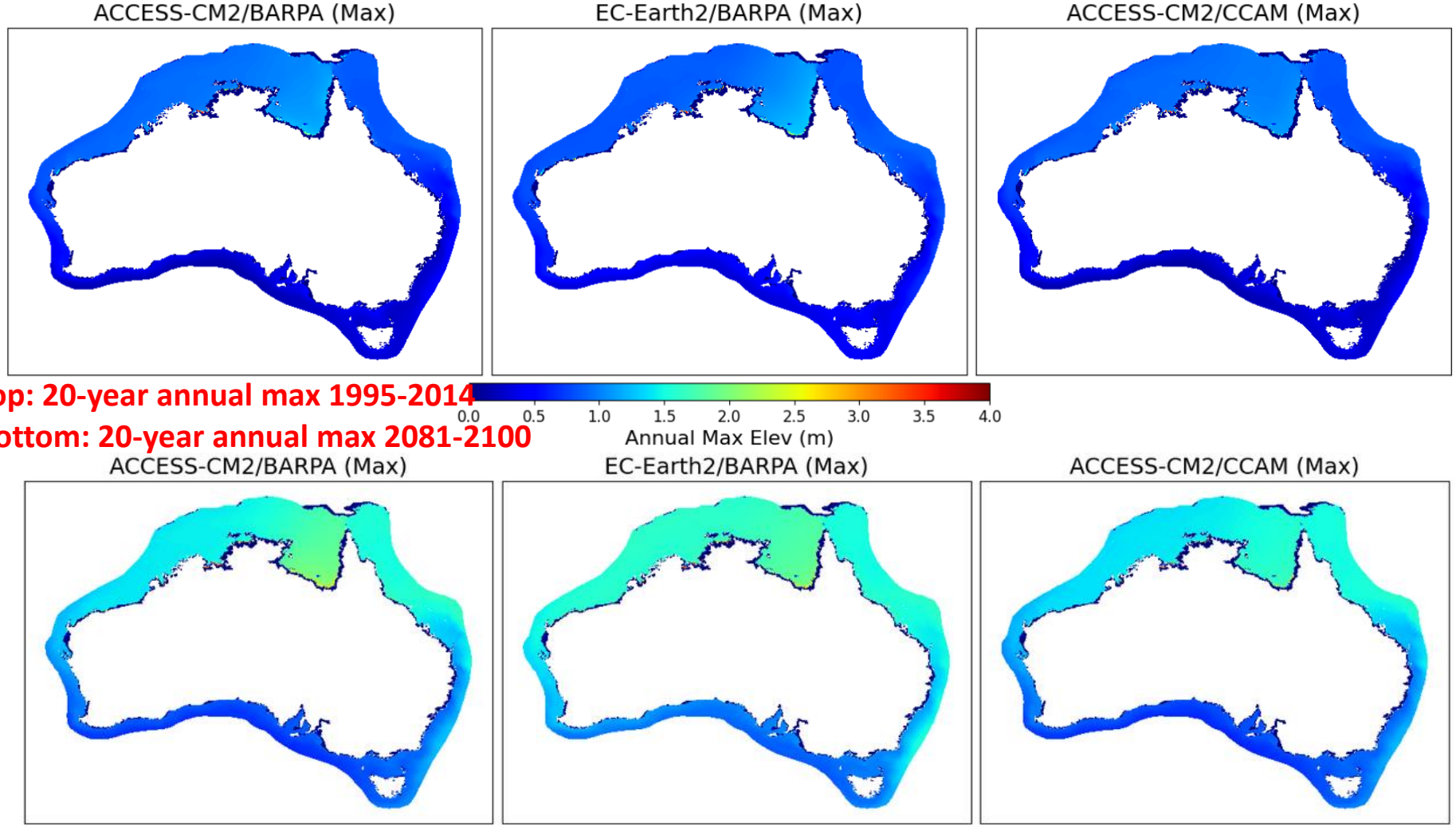
Quantify the different SLR components and their regional variation around Australia

Components of SLR for 2080-2100 relative to 1995-2014



sum to produce total SLR projections for Australia


ACCESS-CM2/BARPA (Mean)
EC-Earth3/BARPA (Mean)
ACCESS-CM2/CCAM (Mean)
Top: 20-year annual mean 1995-2014
Bottom: 20-year annual mean 2081-2100
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Annual Mean Elev (m)


ACCESS-CM2/BARPA (Max)
EC-Earth2/BARPA (Max)
ACCESS-CM2/CCAM (Max)
Top: 20-year annual max 1995-2014
Bottom: 20-year annual max 2081-2100
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Annual Max Elev (m)
ACCESS-CM2/BARPA (Max)
EC-Earth2/BARPA (Max)
ACCESS-CM2/CCAM (Max)

Conclusions and ongoing work

- CCHaPS data publicly available through CSIRO DAP (https://doi.org/10.25919/6tbn-px91). Technical paper in preparation (Hernaman et al., 202?)
- **EVA**: Julian O'Grady: 1, 2, 5, 10, 20 and 63% AEPs with upper and lower 95% confidence intervals for Hs and water levels
- BARRA (like most atmospheric reanalysis) tends to underestimate the intensity of TCs. We're complementing CCHaPS with the **probabilistic TC** work.
- Ongoing analysis to examine differences in projected coastal extremes between the two downscaled GCMs and highlight regional patterns of change in waves and storm surge.
- Using SCHISM-WWMIII for **compound flooding** studies.
- Also conducted 40-year **hydro-only** hindcast to investigate regional differences in contribution of wave processes to coastal extremes, as well as 40-year **tide-only** hindcast.

Thank you

Dr Vanessa Hernaman
Senior Research Scientist

Environment Research Unit, CSIRO

+61 2 9123 4567
Vanessa.Hernaman@csiro.au