The 8th Coordinated Ocean Wave Climate Project Workshop

16-November, 2019.

School of Engineering, University of Melbourne, Melbourne, Australia.

Meeting Report

Prepared by:

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and all meeting participants (listed in Appendix A)

1. Introduction

This short report summarises the 2019 meeting for the Coordinated Ocean Wave Climate Project (COWCLIP), which was held on November 16, 2019 in the Department of Engineering, University of Melbourne, Australia. This meeting occurred on the Saturday following the conclusion of the 2nd International Conference on Waves, Storm Surges and Coastal Hazards (incorporating the 16th International Waves Workshop), held in Melbourne 10-15 November. The venue for the COWCLIP workshop was provided by Prof Ian Young, University of Melbourne. Owing to travel commitments of participants, the workshop followed a shorter format than typical COWCLIP workshops, being a short single day (9am – 2pm).

The primary objective of the meeting workshop was to review the Goals, Aims & Objectives of COWCLIP, and identify key ongoing research challenges best addressed by the COWCLIP community.

Further secondary objectives included:

- Continue to build COWCLIP as a collaborative community of researchers with interests in wind-wave climate variability and change.
- Build community awareness of related programs in development or underway (SeaState CCI; CoastMIP).
- Review recent COWCLIP successes
- Gather an updated perspective of wave climate and related research underway across the COWCLIP community, investigating historical and projected future wave climate variability and change.

The meeting was the 9th in the series of COWCLIP meetings, following

1. the first 2 ½ day COWCLIP workshop held in Geneva, April 2011 (Hemer et al., 2011, 2012) at which COWCLIP formally commenced;
2. a small meeting aligned with the 12th Wave Forecasting and Hindcasting Workshop/3rd Coastal Hazards Symposium in Hawaii, November 2011; This meeting is not considered a COWCLIP meeting in the sequencing.
3. a project 'review' one day meeting, aligned with the 13th Wave Forecasting and Hindcasting Workshop in Banff, in October 2013 (Hemer et al., 2014);
4. A dedicated 2 ½ day workshop in Paris, October 2014 (Hemer et al., 2014a);
5. A dedicated 2 ½ day workshop in Paris September 2015 (Wang et al., 2016a);
6. A session at the 2016 EGU General Assembly in Vienna, April 2016 (Wang et al. 2016b);
7. A one day meeting aligned with the First International Workshop on Waves, Storms Surges and Coastal Hazards, held at the National Oceanography Centre, Liverpool in September, 2017 (Hemer et al., 2018).
8. A dedicated 2 ½ day workshop in Paris, May 2018 (Hemer et al., 2018).

Twenty-seven researchers from across 12 countries attended this workshop (10F, 17M, Senior Professors to PhD students; Appendix A).

The workshop followed the final day of the International Conference on Wind-Waves, Storm-surges and Coastal Hazards, during which two sessions focussed on wave climate research relevant to COWCLIP, with several other posters and presentations through the conference also being relevant.

The meeting spanned three sessions. Following a brief overview of the currently stated goals, aims and objectives of COWCLIP, most recently updated at the 2013 COWCLIP review meeting in Banff (Hemer et al, 2014), participants were sought for input on other items for discussion.

Several topics were discussed:

- The COWCLIP website and data availability

Global projection data climatologies are published on AODN https://catalogue.aodn.org.au/geonetwork/srv/eng/metadata.show?uuid=1de0e8b1-4777-4526-b3d7-805938b8e6bc

This includes consistently formatted climate statistics. A Scientific Data descriptor article is in preparation (Published 2020: Morim et al., 2020; https://www.nature.com/articles/s41597-020-0446-2).

Some discussion was about developing a tool within the website to present COWCLIP data. This would require resources. The open availability of the dataset provides opportunity for users to pick up data, and develop tools as needed.

A need exists to make available sub-daily data. ACTION: Update cowclip.org website to include a database of available sub-daily wave climate projection data. Contributors to contact Adrean Webb, pointing to sub-daily data available (global and/or regional).

Discussion of delivery of historical data. COWCLIP identified as an appropriate program under which to gather, assess and distribute historical data (buoy, satellite, visual wave observations, hindcast, reanalyses). Establish stronger connection with data server (e.g., Copernicus C3S).

In particular, there was appetite for COWCLIP to compile a quality controlled long duration dataset of insitu buoy data. This needs to interact with JCOMM Expert Team for Wave Measurement, with COWCLIP bring climate perspective. COWCLIP can also provide a voice in support of on-going need for in-situ wave measuring networks.

- Visibility of COWCLIP and JCOMM alignment

Recognition that COWCLIP could have more visibility, given now a mature program, and have stronger ties with overarching intergovernmental bodies. E.g., JCOMM.

- Storm Surge equivalent to COWCLIP

There is growing interest in global studies assessing climate change influence on total water level, taking account of thermosteric sea-level, storm surge and wave contributions. COWCLIP has provided a valuable dataset to support assessments of the wave contribution, however 21st Century projections of storm surge remain sparse and uncoordinated. The COWCLIP community has overlap in interest with storm surges, and similarly minded program is of interest to many. The Delft group have recently been progressing a GTSMip activity.

Following this open discussion, the four COWCLIP tasks were introduced briefly. These introductions provided basis for consideration of the challenges and priorities within each task area, to be reported. These task presentations included:

- Historical wave climate change and variability (Li Erikson)
- Regional wave climate projections (Melisa Menendez)
- Global wave climate projections (Mark Hemer)
- GCM-Wave coupling (Nobuhito Mori).

The remainder of the day were focussed on work shaping future direction for COWCLIP, and prioritising the challenges the COWCLIP is best positioned to address.

COWCLIP Aims Discussion

The presently stated aims of COWCLIP are:

- to raise the profile of wind-waves as a variable in the global climate system - both to foster and support determination of:
    - the effects of climate variability and change on the wave climate, and
    - the feedback influences of waves on the coupled ocean-atmosphere climate system.

Workshop session 1 asked users to record their views of the aims of COWCliP on a post-it note, and post this on a specified wall. Participants could include as many items as they wanted. Following the workshop, all items were saved and recorded and these are provided in Appendix B. A number of themes were apparent in responses, including:

- A focus on providing purposeful wave climate data and hazard information to support marine and coastal users
- Joint research to understand historical wave climate variability and change, regionally and globally
- Joint research to establish regional and global projections of 21st Century wave climate variability and change, and understanding associated uncertainties
- Identify and promote the role of waves in the climate system, and motivate coupled model development
- An emphasis on extreme conditions
- COWCLIP as an international focal point, to have a voice to promote wave climate issues (data standardisation, funding opportunities, monitoring needs, modelling needs).

An overview of the perceived aims of COWCLIP from participants is presented as a word cloud, generated by entering all responses into http://wordclouds.com [Figure 1].

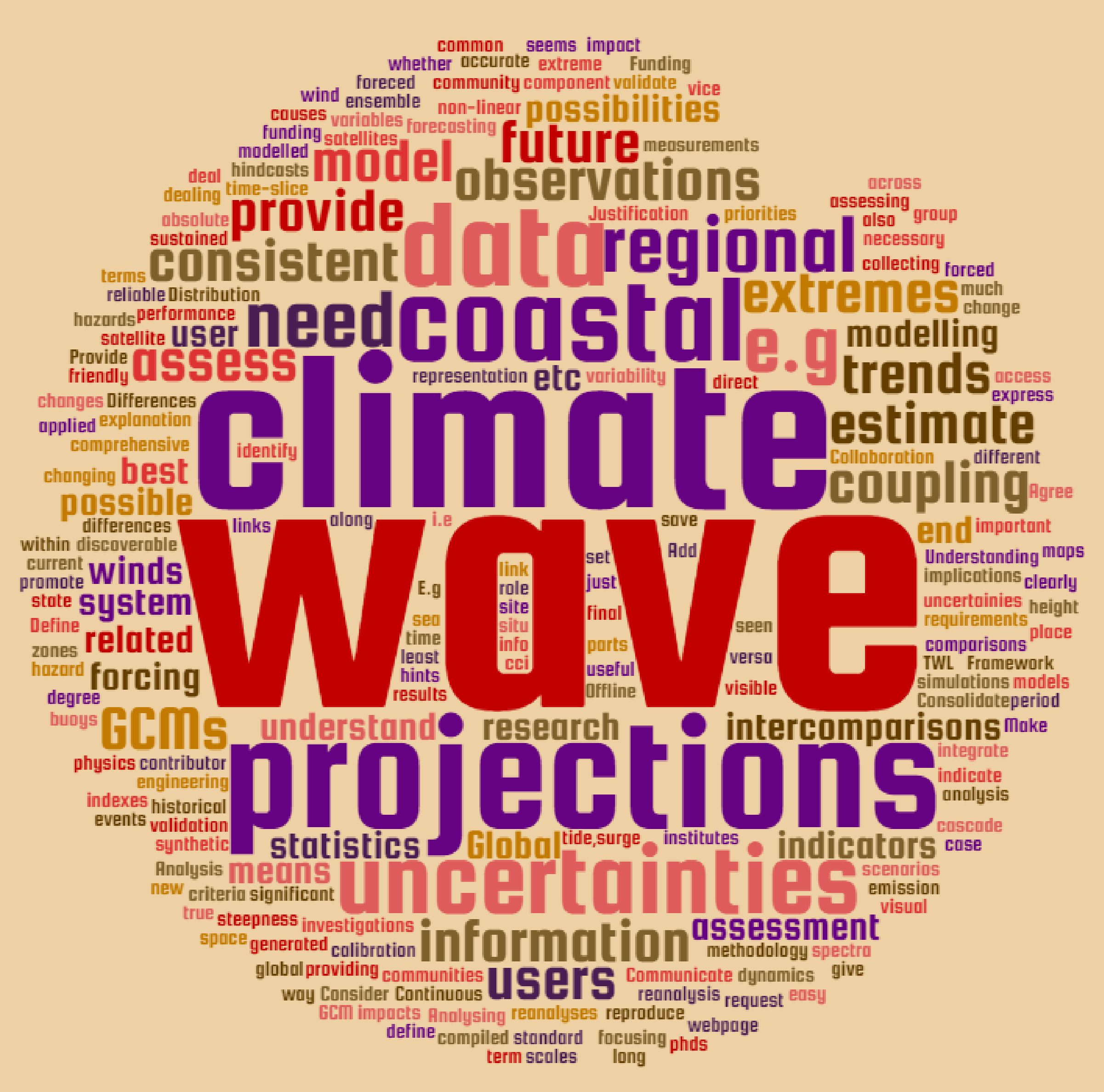

Figure 1. Wordcloud using documented responses of COWCLIP aims from workshop participant.

Following these outputs, the existing COWCLIP aims were thought to capture the majority of scope identified. A minor edit is added, to emphasise the end-user driven focus of the group.

Proposed COWCLIP aims:

- To raise the profile of wind-waves as a variable in the global climate system - both to foster and support determination of:
    - the effects of climate variability and change on the wave climate, and
    - the feedback influences of waves on the coupled ocean-atmosphere climate system.

and support delivery of purposeful wave climate information for marine and coastal users.

COWCLIP Goals

The presently stated COWCLIP goals are to:

1. Establish a collaborative working group with interest in global wave climate historical and future variability and change

2. Resolve priority questions to aid climate impacts community

3. Document wave climate projections methods being applied, and summarise existing wave climate projection studies

4. Define a working protocol for wave climate projections:

    a. Agreed standard inter-comparison experiments to obtain adequate coverage of sampling space, to establish variance associated with several layers of uncertainty

    b. Minimum set of analyses/validation requires to foster inter-comparisons (projections and coupled models independently)

5. Develop a technical framework to support the working group

    a. Project data server, QC, standard variables, etc

The second workshop session carried out a similar session, focused on the Goals of the COWCLiP.

Participant sourced suggestions for COWCLiP goals are listed in Appendix C. Figure 2 presents a word cloud from provided input.

Figure 2. Wordcloud using documented responses of COWCLIP goals from workshop participants.

Following the participant sourced input, a set of revised goals are proposed here:

1. Be the authoritative community working group, fostering collaboration and interest in global wave climate historical and future variability and change
2. Resolve priority wave climate research challenges to aid climate impacts community
3. Develop evidence for the influence of waves in the global climate system, and continue to motivate incorporation of wind-waves into seamless Earth System Prediction systems.
4. Build reliable historical and future projected wave climate datasets for the user community; both observational, and modelled datasets leveraging latest forcing datasets.
5. Develop and document appropriate technical protocols, frameworks and standards [Project data server, QC, set of analyses/validation, standard variables] to:
   i. Define agreed community experiments to ensure adequate coverage of sampling space and foster intercomparison
   ii. Ease access to wave climate data by users

Task 1 – Historical variability and change

The following workshop sessions focussed on each of the four COWCLIP Tasks. The first of these being ‘Historical variability and change’.

Participants were asked to record priority research questions within the given task area, and post this on a chart with axes of Ease (1 being difficult, to 10 being easy) vs Impact or Importance (1 being low, to 10 being high). The participant sources ideas are provided in Appendix D. Figure 3 displays a word cloud compiled from responses.

Figure 3. Wordcloud using documented responses from workshop participants of the priority research challenges aligned with Task 1 – historical variability and change.

While Appendix C contains all reported items, here we include the most prioritised activities (by impact); that vary across a range of perceived difficulty.

Ease (difficult 1:10 easy)	**Impact (low 1:10 high)**	**Activity**
7	10	Set standard method to estimate uncertainty in trends during historical period
4	10	Impact on trends: assess uncertainty due to internal variability. Not good coverage of all sources of uncertainty. Ensemble members not independent. Weight some models more than others, for example.
1	10	set up global observation network for waves (like GLOSS for tide gauges)
9	9	making comprehensive long-term global buoy data
6	9	define consistent / benchmark historical wave climate
2	9	baseline in-situ and satellite datasets

Task 2 – Regional Projections

The second task discussion focused on the priority research challenges associated with regional projections. Using the same process, a list of priorities was established (Appendix E). Figure 4 shows an associated word cloud.

Figure 4. Wordcloud using documented responses from workshop participants of the priority research challenges aligned with Task 2 – Regional projections.

Below we list priority activities (on basis of impact).

Ease (difficult 1:10 easy)	Impact (low 1:10 high)	
10	10	Use same time periods - move historical period for comparison as moving forward
9	9	Define standards for modelling
8	9	how do global and regional projections tie together
8	9	how do regional projections compare with global
6	9	morphological / SLR induced changes to wave climate
4	9	atmospheric downscaling uncertainty
2	9	Using regional models to progress understanding of waves to total sea level projections
2	9	regional intercomparisons - variability and uncertainties

Task 3 – Global Projections

The third task discussion related to Global projections. The reported research challenges are given in Appendix F. Figure 5 presents an associated wordcloud.

Figure 5: Wordcloud using documented responses from workshop participants of the priority research challenges aligned with Task 3 – Global projections.

Below we list priority activities (on basis of impact).

Ease (difficult 1:10 easy)	Impact (low 1:10 high)	
9	9	seamless projection
8	9	CMIP6 continuous projections
7	9	Mid century wave projections for adaptation purposes
5	9	uncertainty on extreme waves projections
3	9	Global assessment of coastal impacts. Very challenging but needed. Particularly since regional modelling not available everywhere. Identify hot spot areas.
2	9	extremes

Task 4 – Wave-GCM Coupling

The final workshop session focused on research challenges associated with Task 4 – coupling of waves into general circulation models. The identified research challenges are listed in Appendix G, and associated wordcloud presented in Figure 6.

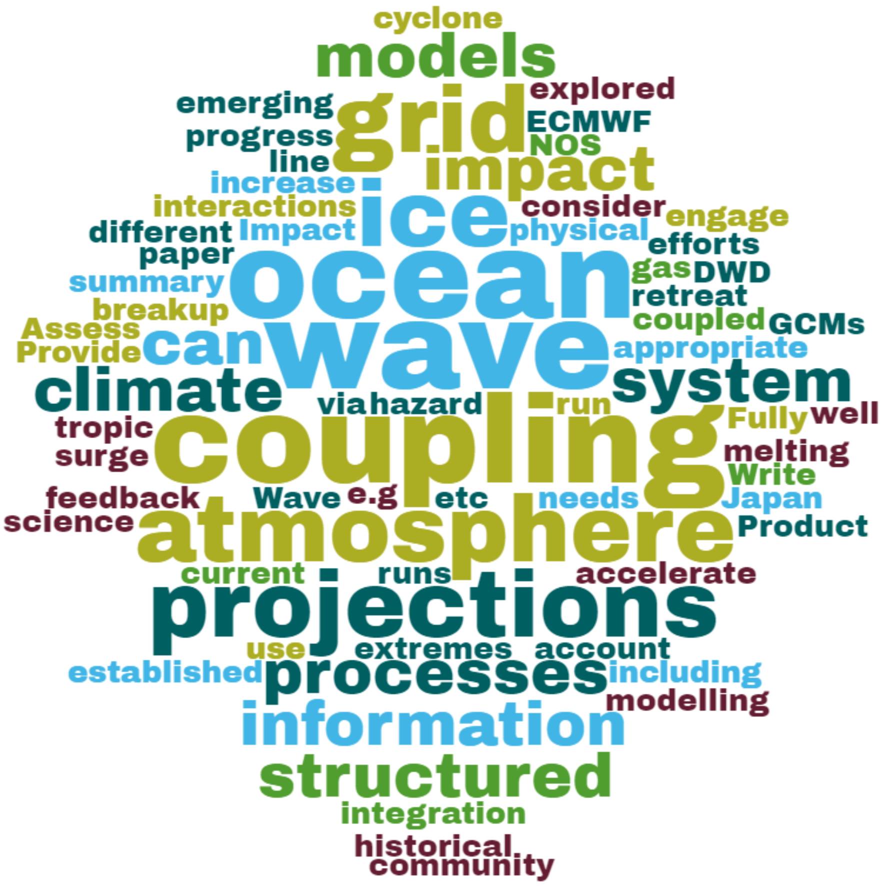

Figure 6. Wordcloud using documented responses from workshop participants of the priority research challenges aligned with Task 4 – Wave-GCM coupling.

Below we list priority activities (by impact).

Ease (difficult 1:10 easy)	Impact (low 1:10 high)	
1	10	wave ice feedback. Wave impact on icea breakup melting can further accelerate ice retreat, can further increase waves
2	9	Impact and hazard information only with coupling waves ocean atmosphere e.g. extremes
1	9	account for wave current processes in climate projections

7. Summary

Figure 7 displays the active participation undertaken in the workshop.

Finally, the discussion was opened to include any other business.

Figure 7. Photos documenting workshop discussions.

Topics raised included the timing and venue for the next COWCLIP meeting. Several options were discussed, with the most likely to be alignment of COWCLIP with upcoming meetings of the ESA SeaState CCI, scheduled for early 2021.

The meeting was closed at approximately 130pm, with Chairs thanking participants for their active involvement making for a successful meeting. This workshop introduced more active involvement in defining some priority activities, which had not been trialled in prior COWCLIP meetings. The format seemed successful in gaining input within a short time period, to help define a way forward for COWCLIP activities.

Following the meeting close, the group adjourned for lunch at a nearby Italian restaurant in Lygon St.

Acknowledgements.

COWCLIP is a community activity. We thank all attendees for their active participation, interrogating questions and discussions (formal and informal) at the workshop.

We thank the University of Melbourne for their administrative support for the workshop. In particular, Ian Young.

We acknowledge input of others who were unable to attend the workshop, expressing apologies, who have contributed data or made other contributions to the current COWCLIP tasks.

Chair Mark Hemer acknowledges support of the Australian Government Earth Systems and Climate Change Hub, to support leadership of the project.

References

Hemer, M.A., X.L. Wang, R. Weisse, & the COWCLIP team (2011). WCRP-JCOMM Workshop on Coordinated Global Wave Climate Projections (COWCLIP). *JCOMM Technical Report No 55, JCOMM-TR-055, WMO/TD-No. 1581, WCRP Informal Report No. 22/2011, SPA_ETWS_COWCLIP_01.* Available at: https://www.jcomm.info/index.php?option=com_oe&task=viewDocumentRecord&docID=7469

Hemer, M.A., X.L. Wang, R. Weisse, & V.R. Swail (2012). Community advancing wind-waves climate science: The COWCLIP project. Bull. Amer. Meteor. Soc., 93(6), 791-796. DOI: 10.1175/BAMS-D-11-00184.1.

Hemer et al. (2014). Coordinated Ocean Wave Climate Project (COWCLIP) Review. Final Report of the Review Meeting, Banff, Canada, 1-2 November 2013. *JCOMM Technical Report No. 76*. Available at: http://www.jcomm.info/components/com_oe/oe.php?task=download&id=24410&version=1.0&lang=1&format=1

Hemer, M., X. L. Wang, E.Charles, C. Hegermiller & COWCLIP contributors (2014a). Report of the 2014 Meeting for the WCRP-JCOMM Coordinated Ocean Wave Climate Project (COWCLIP), Paris, 1-3 October, 2014. *JCOMM Technical Report 82*. Available at: http://jcomm.info/components/com_oe/oe.php?task=download&id=26840&version=1.0&lang=1&format=1

Hemer, M., L. Erikson, X.L. Wang, and A. Webb (2018) Report of the 2018 Meeting of the WCRP-JCOMM Coordinated Ocean Wave Climate Project. May 2018. JCOMM Technical Report 92. Available at: https://www.jcomm.info/index.php?option=com_oe&task=viewDocumentRecord&docID=22378

Morim, J., Trenham, C., Hemer, M. et al. A global ensemble of ocean wave climate projections from CMIP5-driven models. Sci Data 7, 105 (2020). https://doi.org/10.1038/s41597-020-0446-2

Wang, X.L., M.A. Hemer & COWCLIP contributors (2016a). Report of the 2015 Meeting of the WCRP-JCOMM Coordinated Ocean Wave Climate Project. 2-4 September 2015. JCOMM Technical Report 88. Available at: http://www.jcomm.info/index.php?option=com_oe&task=viewDocumentRecord&docID=17213

Wang, X.L., M.A. Hemer & COWCLIP contributors (2016b). Report of the 2016 Meeting of the WCRP-JCOMM Coordinated Ocean Wave Climate Project. May 2016. JCOMM Technical Report 89. Available at: https://www.jcomm.info/index.php?option=com_oe&task=viewDocumentRecord&docID=17916

APPENDIX A – REGISTRANTS

Attendees: 27 attendees, 16 organisations, 12 countries

Name	Institute	Country
Adrean Webb	Kyoto University	Japan
Agustinus Ribal	University of Melbourne	Australia
Alberto Meucci	University of Melbourne	Australia
Cagil Kirezci	University of Melbourne	Australia
Christine Gommenginger	NOC	UK
Claire Trenham	CSIRO	Australia
Ebru Kirezci	University of Melbourne	Australia
Francesco de Leo	University Genoa	Italy
Giovanni Besio	University Genoa	Italy
Guillaume Dodet	IFREMER	France
Ian Young	University of Melbourne	Australia
Jean Bidlot	ECMWF	UK
Joanna Staneva	HZG	Germany
Li Erikson	USGS	USA
Lorenzo Mentaschi	JRC	Italy
Luciana Bertotti	ISMAR	Italy
Luigi Cavaleri	ISMAR	Italy
Mark Hemer (Chair)	CSIRO	Australia
Melisa Menendez	IH Cantabria	Spain
Merce Casas-Prat	Environment and Climate Change Canada	Canada
Nobuhito Mori	Kyoto University	Japan
Ole Johan Aarnes	Met Norway	Norway
Tom Durrant	Oceanum Ltd	New Zealand
Tomoya Shimura	Kyoto University	Japan
Vika Grigorieva	SIO	Russia
Vit Sharmar	SIO	Russia
Xiaolan Wang (Co-Chair)	Environment and Climate Change Canada	Canada

Apologies were received from: Alex Babanin (UMelb), Christian Appendini (UNAM, Mx), Alvaro Semedo (IHE, The Netherlands), Joao Morim (Griffith Uni).

Figure A1 – Photo of COWCLIP 2019 attendees.

Back row: Agustinus Ribal, Luigi Cavaleri, Tomoya Shimura, Alberto Meucci, Francesco de Leo, Joanna Staneva, Mark Hemer, Merce Casas Prat, Ian Young, Nobuhito Mori, Ole Johan Aarnes, Guillaume Dodet, Cagil Kirezci

Front row: Li Erikson, Xiaolan Wang, Vika Grigorieva, Lorenzo Mentaschi, Luciana Bertotti, Melisa Mendendez, Claire Trenham, Adrean Webb, Giovanni Besio, Jean Bidlot, Christine Gommenginger, Ebru Kirezci, Vit Sharmar

Absent from photo: Tom Durrant

APPENDIX B

COWCLIP Aims and Objectives: workshop participant sourced suggestions

Provide climate hazard information to support marine and coastal users
Distribution of significant data to end users
user friendly, discoverable webpage
consistent regional projections with indicators / intercomparisons / data and info for end users (e.g., impact, hazards)
to be a go to place/ site for wave projections (whether generated within the group or just compiled)
reliable information on coastal hazard
To understand users who need this data, the final contributor. Global statistics are useful for model intercomparisons but not consistent with observations
clearly indicate the implications of the climate change variables for the coastal community
Consolidate links between applied wave research (e.g., coastal engineering, forecasting) and climate projections (and vice versa)
assess current and future requirements on sea state data
Understand historical wave climate change
provide best estimate of historical wave climate
promote the need for long term sustained consistent in situ measurements of waves (e.g., for satellite calibration and validation)
To estimate the trends in terms of wave height and steepness. It seems to be more 'visible' than trends in wave period.
assess changes in wave climate at global and regional scales
Understand climate change projections influence on wave climate
Global to regional: degree to km
Continuous projections (from time-slice)
Analysis of forcing emission scenarios
define a common methodology to assess future trends
provide wave climate projections with explanation of causes
Provide easy access wave projections results . i.e., maps
Promote waves as climate variable
Motivate consideration of waves into GCMs
Define and understand the role of waves in the climate system
identify the necessary component of wave related physics in GCMs
link wave investigations with related parts of the climate modelling system; GCMs coupling and coastal impacts (tide,surge, IB, etc to TWL with waves)

On/ Offline coupling with GCMs
Make the case that GCM coupling to waves is important in a changing climate
Consider uncertainties when dealing and focusing on coastal zones
Add uncertainies of all data - model do not give absolute true
how to deal with uncertainties of projections / assessment / indicators
Understanding and do further analysis of the 'cascade of uncertainties' for wave climate projections
Differences across models foreced with same forcing. Justification that comprehensive assessment of differences in means, extremes and their variability in the hindcasts modelled by the same model, but forced with different reanalyses. This also hints on the representation of reanalysis dynamics that not be seen from direct comparisons of winds, as waves integrate wind in non-linear way in space and time.
Communicate best estimate and uncertainties
Agree on new 'standard' indexes /criteria. E.g, for extremes
Analysing performance of climate simulations to reproduce extremes events
Framework for collecting and assessing extreme wave statistics
to express the need for a cci for winds
Funding
possibilities for phds
funding possibilities
more accurate regional information.
Collaboration with other communities
request modelling institutes to save 2d spectra as much as possible (at least along coastal)
synthetic information for user (e.g., ensemble means and uncertainties)
provide a set of priorities for future research on wave climate
Before providing the data, we need to validate it against all possible observations: satellites, visual observations, buoys etc.

Appendix C

COWCLIP Goals: Workshop participant sourced suggestions

Goals
Quantify historical and future wave climate
Determine magnitude of wave climate change and uncertainties
Develop the evidence about the impact of waves on the global climate system
Geographical user interface which shows the available data for the selected region (google earth based)
Data framework to make access to wave climate change data easier
Include a user interface that facilitates the understanding of the climate variability for the variety of contributors
Build reliable wave climate datasets for the user community
Build a wave climate community and foster joint research
Increase COWCLIP visibility, e.g., through connection with other initiatives (Copernicus interactive data/web site/ Acces easy and user friendly)
preliminary user stakeholder survey
identify priority research challenges in wave climate
include storm surge variability projections in combination with waves to reflect the implications on coastal flooding adaptation etc
leverage latest global forcing datasets (era5, cmip6 etc)
higher profile in IPCC report (x2)
standardised classification of dataset quality
Continue to develop or work to get IPCC to include COWCLIP recommendations
Regional downscaling
Regional projections
multi-hazards beach surge SLR
extreme wave climate
collection of observational datasets
include wave models in GCMs (climate models)
wave contribution to sea ice breaking / melting - large interest due to climate implications and feedback processes
provide recommend more relevant wave climate data for coastal impact study
extreme
compound events climate change increases dependencies between extremes. Investigate how this affects wave extremes in relation to other extremes
extremes and connected uncertainties
integrating waves with other components of coastal hazard

clear indication of the methods applied and associated uncertainties for each dataset
extend wave climate change studies to the full spectra information
ensemble climate projections - to create an ensemble, the methods can be different but they should be consistent. Otherwise we cannot compare them.
providing information on the extemes
availability of the results - who decides which projections are better. How can the user deal with this problem? Is COWCLIP offering all projections or a unified product?
Uncertainties of the results are associated not only with future climate scenarios but also with the physics of the wave models used
assessment wave driven coastal hazards at global scale? Similarly as SLR communityy with water levels better interaction with coastal community.
work with infrastructure engineering community to think how changes in wave extremes might affect building codes and design criteria. How to deal with uncertainties
wave relevance with climate projections: a stormy sea increases the atmosphere ocean exchange by at least an order of magnitude. 20% of the ocean is statistics under stormy conditions; This means that the extremes influence climate
to understand the uncertainties in waves to uncertainties in wind
coordinate wave projections experiments for better assessment of uncertainties
coordinate to better assess uncertainties; bias corrected historical simulation vs non bias corrected historical simulation; otherwise part of wave model variability is actually GCMs variability
analyse how interannual interdecadal wave variability can change under wave climate change scenarios
investigate how to connect future biases based on current biases? Dependence between variables
related data processing - find a protocol to estimate ensemble outputs and related uncertainty
careful use of ensemble might mask extremes. Investigate how to better deal with uncertainties. Storylines. Extremes feasible cases?
support community working group
agreed standard experiments, data structures and processing codes to minimise systematic uncertainties
assessing uncertainties in long term historical records
assessing uncertainties in long term historical climate simulations

Appendix D

Task 1: Historical Variability and Change. Participant sourced research challenges

Ease (difficult 1:10 easy)	Impact (low 1:10 high)	
7	10	set standard method to estimate uncertainty in trends during historical period
4	10	impact on trends: assess uncertainty due to internal variability. Not good coverage of all sources of uncertainty. Ensemble members not independent. Weight some models more than others, for example.
1	10	set up global observation network for waves (like GLOSS for tide gauges)
9	9	making comprehensive long term global buoy data
6	9	define consistent / benchmark historical
2	9	baseline in-situ and satellite datasets
8	8	homogenise wave observations
7	8	define priorities for improving historical trend estimates
4	8	reliable wind datasets
2	8	if someone needs visual observations for validation against altimeter measurements or and model hindcasts, don't hesitate to ask me about vika@sail.msk.ru (Vika Grigorieva)
10	7	tailor wave model output for extreme analysis
6	7	downscale to impact relevant scales
1	7	Coastal sea level: assess historical changes in the nearshore zone.
6	6	NOAA/ CIRES 20CRV3 reanalysis for 1836-2016 (80 members). 20CRV3 based wave simulations on intercomparions (also compared to other reanalysis datasets)
5	6	separate linear trend from long term oscillations
3	6	convince reanalysis providers that extremes are more important than mean climate
9	5	systematic set of reanalysis forced models - coordinate reanalyses and methods used
5	5	variability amongst altimeter datasets
6	4	improve representation of waves in TCs /extremes / storms
8	2	validate performance of historical wave climate runs (trends)

Appendix E

Task 4 – Regional variability: Participant sourced research challenges.

Ease (difficult 1:10 easy)	Impact (low 1:10 high)	Activity
10	10	Use same time periods - move historical period for comparison as moving forward
9	9	Define standards for modelling
8	9	how do global and regional projections tie together
8	9	how do regional projections compare with global
6	9	morphological / SLR induced changes to wave climate
4	9	atmospheric downscaling uncertainty
2	9	Using regional models to progress understanding of waves to total sea level projections
2	9	regional intercomparisons - variability and uncertainties
8	7	Cordex(2)-forced wave models (mirror IPCC)
7	7	define regional areas
7	7	identify priority areas for community regional areas
5	7	bias correction of wave changes for impact studies
4	7	regional intercomparison study for the arctic
2	7	resolution required to conduct a regional projection
6	6	high resolution virtual TCs runs and projections
9	5	Relate regional projections to global projections
5	5	how to propagate bias correction to future projections (e.g., arctic very challenging)
3	5	assessment of differences between regional and global projections to observe the effect of regional systems
2	5	develop dedicated RCM
8	4	need to coordinate projections to better sample and assess uncertainty
5	4	SLR impact on waves
3	4	summarise wave projections in storylines that are relevant for impact studies
2	4	regional and coupled
8	2	Provide regional data easily available
8	2	Update regional studies database

Appendix F

Task 3 – Global Projections. Participant sourced research challenges

Ease (difficult 1:10 easy)	Impact (low 1:10 high)	
9	9	seamless projection
8	9	CMIP6 continuous projections
7	9	Mid century wave projections for adaptation purposes
5	9	uncertainty on extreme waves projections
3	9	Global assessment of coastal impacts. Very challenging but needed. Particularly since regional modelling not available everywhere. Identify hot spot areas.
2	9	extremes
10	8	Use same time periods. Move historical period for comparison as moving forward
4	7	Review of global extreme waves projections
2	7	validation of future change
9	6	Tailor better the output from wave model for climate studies purpose
7	6	CMIP6 forced wave models mirror IPCC assessment windows
6	6	separate linear trend from long term oscillations
5	6	analysing wave changes on other spectral conditions that standard sea state parameters (sea, swell changes)
3	6	global coastal impact implications
5	5	how to summarise in storylines of wave projections. Perhaps avoid and just use ensemble mean and uncertainties
6	4	Need to coordinate projections to better sample and assess uncertainty
9	2	Historical trends in GCM forced wave studies

Appendix G

Task 4 – Wave-GCM Coupling. Participant sourced research challenges.

Ease (difficult 1:10 easy)	Impact (low 1:10 high)	
1	10	wave ice feedback. Wave impact on icea breakup melting can further accelerate ice retreat, can further increase waves
2	9	Impact and hazard information only with coupling waves ocean atmosphere e.g. extremes
1	9	account for wave current processes in climate projections
4	7	Wave ocean coupling is emerging science needs to be explored further
5	6	Wave atmosphere coupling is well established - use it
1	6	integration coupling with surge tropic cyclone etc models
4	5	Product run of coupling system
2	5	Fully coupled system for projections consider appropriate physical processes on interactions
10	4	Write summary paper on impact of waves on atmosphere and ocean
1	4	Wave-gas coupling
10	3	Assess progress of different coupling efforts (ECMWF, DWD, Japan, NOS)
4	3	How to engage climate modelling community who including waves
2	3	Unstructured grid wave models coupling with structured grid GCMs (via structured grid waves)
8	2	Provide ocean information as off line coupling for historical runs and projections