The Coordinated Ocean Wave Climate Project: Achievements to date and outstanding challenges

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for the COWCLIP group

http://www.jcomm.info/cowclip

COWCliP 2017 attendees

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Apologies:

Piero Lionello (Italy), Will Perrie (Canada), Alex Babanin (Umelb), Christian Appendini (Mexico), Morten Rugjberg (DHI)

Issue and Background

* [Coastal climate] Impact and adaptation assessments and planning require consideration of a range of different [sea-level] drivers - mean changes (including uplift/subsidence), extremes and waves.

WCRP Sea-Level 2017 Conference Statement, Aug 2017.

The challenge

- Waves will respond to variability and change in the global climate system.
- Changing storm tracks/intensity will drive changes in global wave field, having potential implications on:
  - Coastal stability/impacts/management
  - Off-shore platform design/installation (O&G and Offshore Renewables)
  - Ship design and route planning
  - Feedback processes via altered air-sea fluxes of heat/mass/radiation/salt
- Uncertainty currently dominates signal

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.

COWCliP (2014). JCOMM Technical Report.

COWCliP goals:

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

COWCLIP Workshop 1 JCOMM Report (2011).

Wave Climate Summary

Data to Archive: 4 variables x 7 statistics x 17 time-ranges per simulation.

4 variables:

- Significant Wave Height
- Mean Wave Period, Tm01
- Mean Wave Direction
- Swell Wave Height (if possible)

7 Statistics:

The mean, the 10^{th}, 50^{th}, 90^{th}, 95^{th} and 99^{th} percentiles, and max (from 6-hourly data), for

17 time-frames:

12 monthly, 4 seasonal (DJF, MAM, JJA and SON), and an annual value for each year of record.

Spectra & return period wave conditions were considered outside scope of inter-comparisons.

OWCliP
Ocean Wave Climate

COWCLIP has four interconnected themes:

Wave – GCM coupling development: Understand effects of waves in coupled climate system

Global wave projections: Providing guidance for adaptation and impact studies

Regional wave projections: providing guidance for localised impact studies

Wave Climate Baseline: Characterising past wind-wave climate change & variability

COWCLIP Ocean Wave Climate

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Historical variability and change

* Historical wave climate studies assess a range of datasets:
  - ***Satellite Remotely Sensed*** (e.g., Young et al., 2011, Liu et al., 2016)
    - Altimeters (1985-present), SAR
  - ***In-situ Measurements*** (e.g., Bacon & Carter, 1991, Ruggiero et al., 2010, Gemmrich et al., 2011)
  - ***Reanalyses*** (Caires & Sterl, 2005, Aarnes et al., 2015, Kumar et al., 2016)
    - ERA-40 reanalysis (1958-2001)
    - The KNMI corrected ERA-40 Dataset (1958-2001)
    - ERA-Interim reanalysis (1979-present)
  - ***Hindcasts*** (e.g., Stopa et al., 2013, Marshall et al., 2016, Aguirre et al., 2017)
    - NCFS forced hindcasts (several groups: 1979-ongoing)
    - JRA-55 hindcast (1958-2012)
  - ***Visual Observations*** (e.g., Gulev et al., 2004, Soomere et al., 2007, Grigorieva et al., 2016)
  - ***Seismological*** (e.g., Grevemeyer et al., 2000, Bromirski et al., 2012)
* Studies span all regions of global ocean
* Studies focus on climatology, trends, and wave climate response to atmospheric modes of variability

Historical variability and change

- Good baseline critical!
- Not in a position to say one dataset is superior to any other
- Priority is to understand how and why datasets differ in representation of wave climate
- Increasing recognition of sea-state as an ECV within GCOS, requires concerted communal effort to resolve these differences and establish a consistent historical wave climate record.

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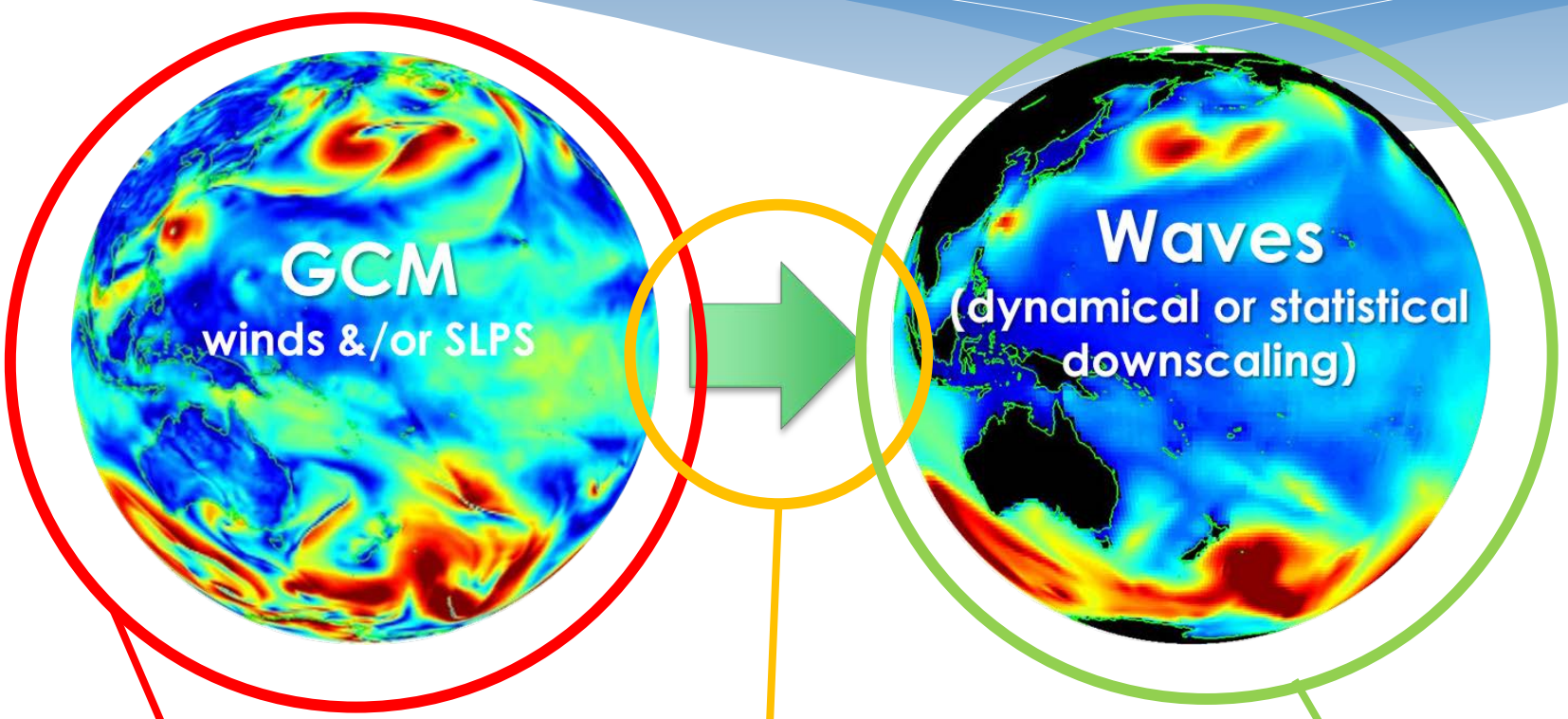
Future wave climate change



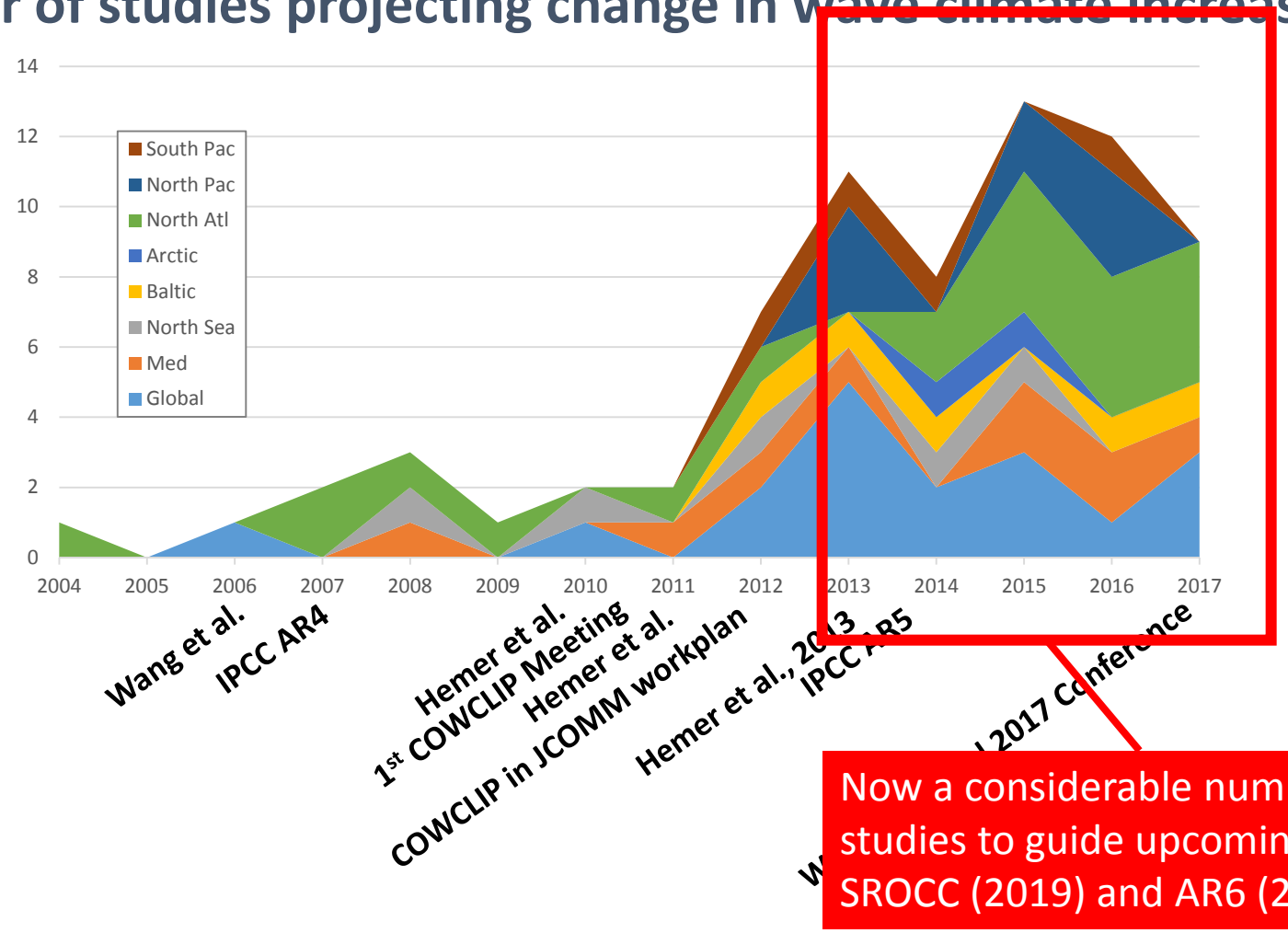
- Scenario uncertainty
- Inter-model uncertainty
- Intra-model uncertainty

- Atm. downscaling uncertainty
- Statistical/Dynamical methods

- Wave model uncertainty
- Statistical/Dynamical methods
- Source terms

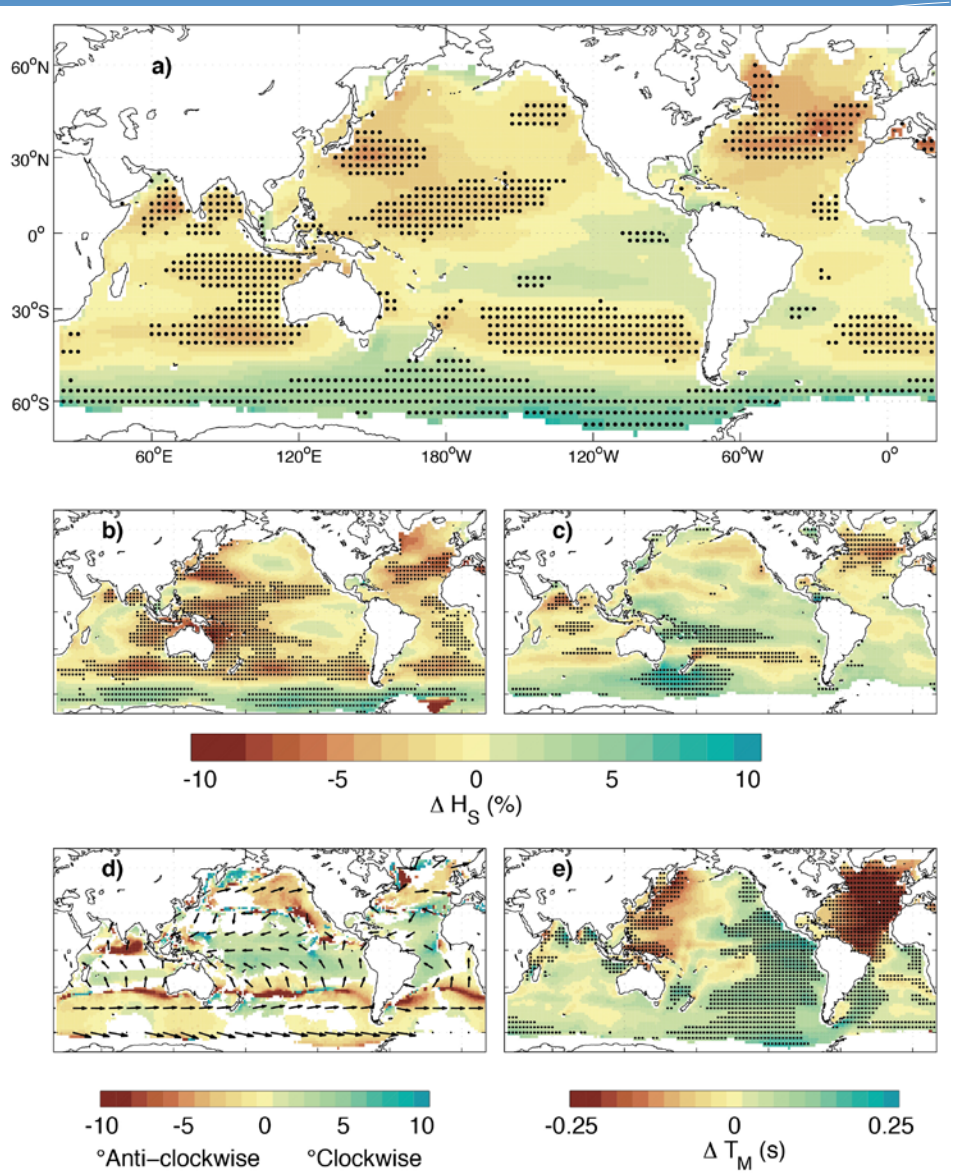
Future wave climate change

Number of studies projecting change in wave climate increasing



21st Century Global Wave Projections

- Phase 1 (CMIP-3) inter-comparison provided first community projection of global wave climate change.
- Phase 1 ensemble of opportunity had little overlap in sample space, resulted in high – unquantifiable – uncertainty in projected wave conditions.
- Phase 2 (CMIP-5) experiment is designed to overcome phase-1 shortcomings.



Hemer et al. (2013) Nature Climate Change, Church et al. (2013), IPCC AR5

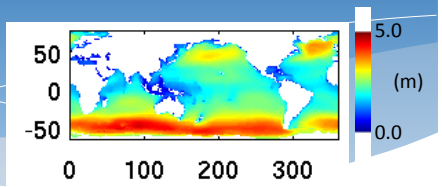
OWCliP Ocean Wave Climate

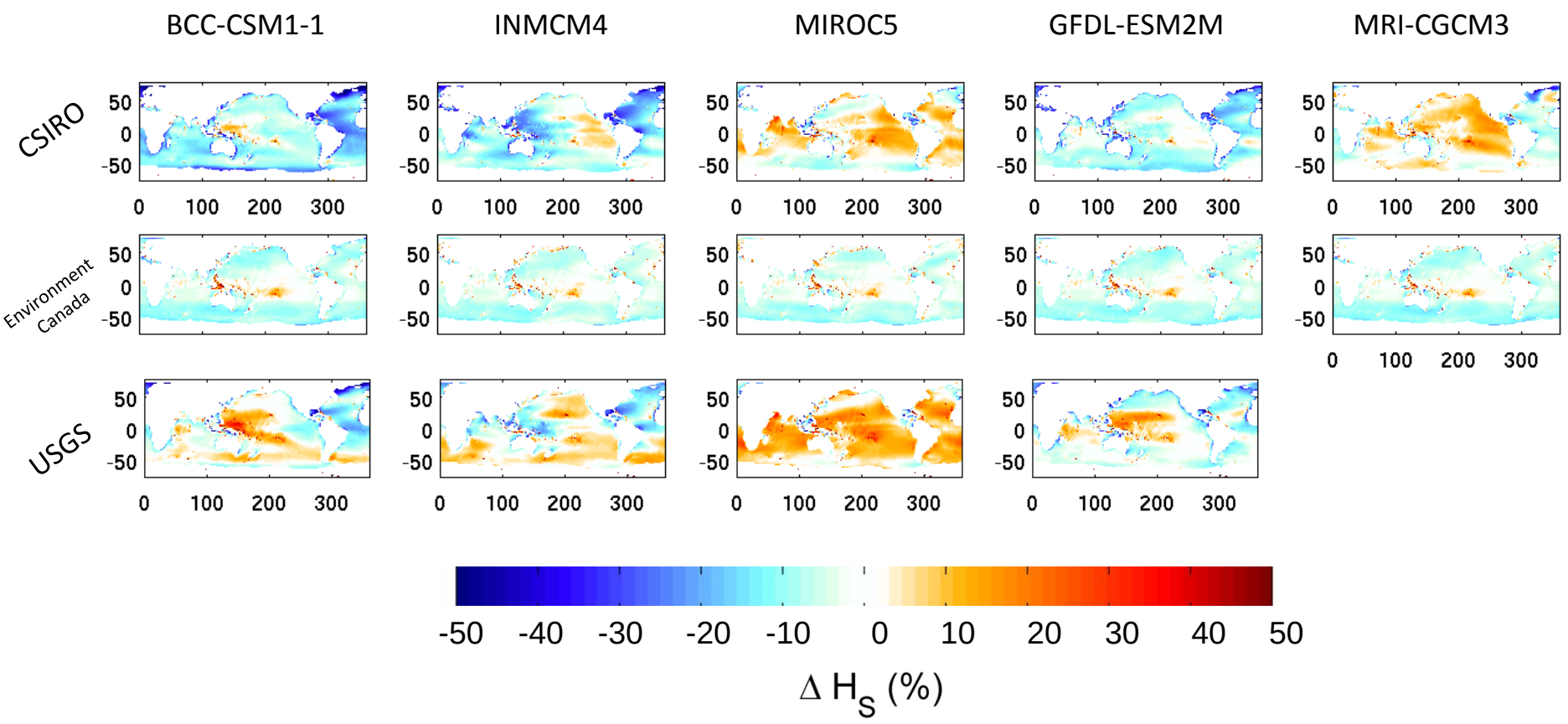
COWCLIP Phase II

- Remove time-slice uncertainty
  - Standardising time-slices
    - Historical 1980-2005
    - End 21st Century: 2080-2100
- Remove parameter uncertainty
  - Standardised parameters for comparison.
- Remove scenario uncertainty
  - RCP4.5 & RCP8.5 simulations
- Remove intra-model uncertainty
  - Several groups have completed wave simulations using same GCM forcing (BCC-CSM1.1, INMCM3, EARTH-EC, GFDL-ESM2M, MIROC5, and some others).
- Isolate variance associated with scenario, alternate GCMs, and wave downscaling methodologies.
- Several (>6) groups contributing (to be finalised/resolved in COWCLIP 2017 meeting)

Historical annual mean percentage H_S bias:

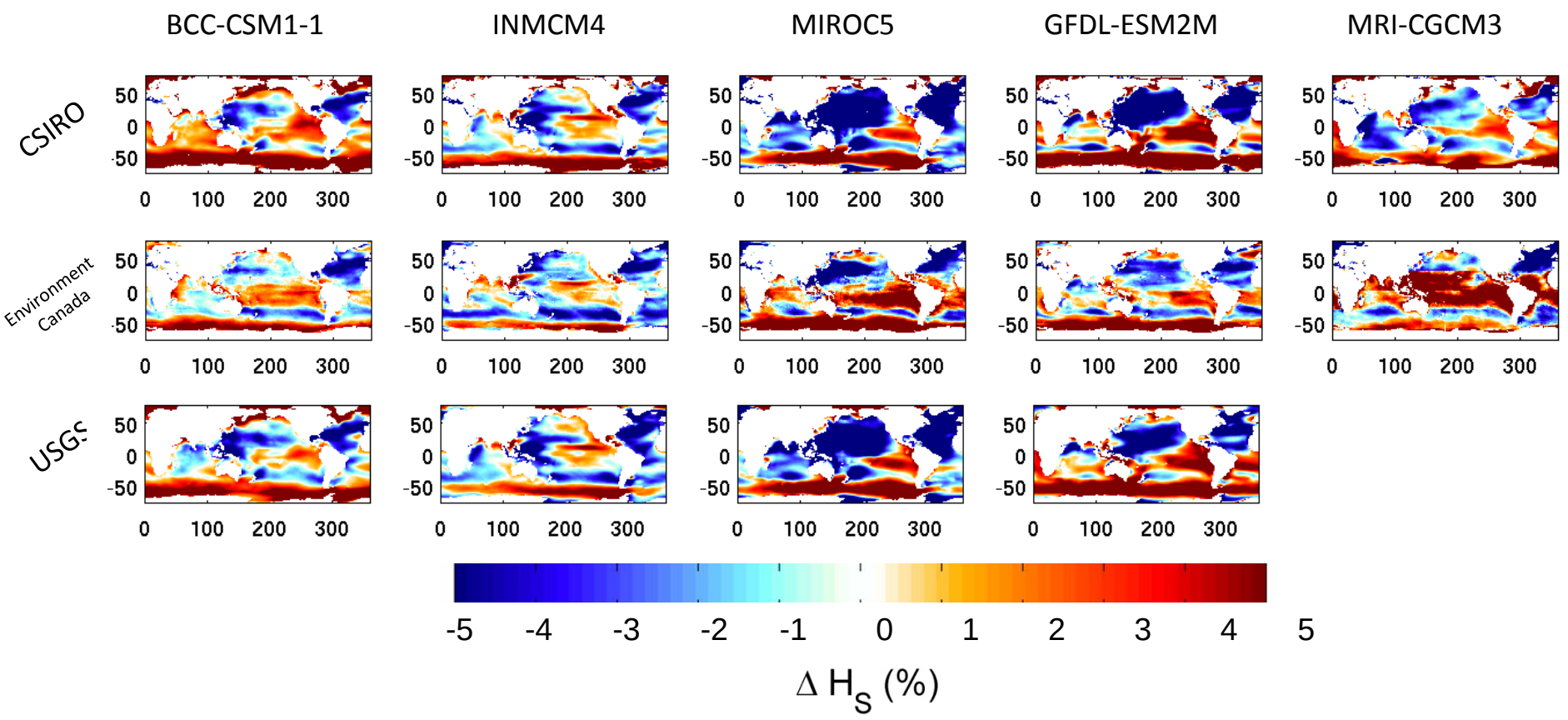
Relative to CAWCR wave hindcast (NCFSR winds)



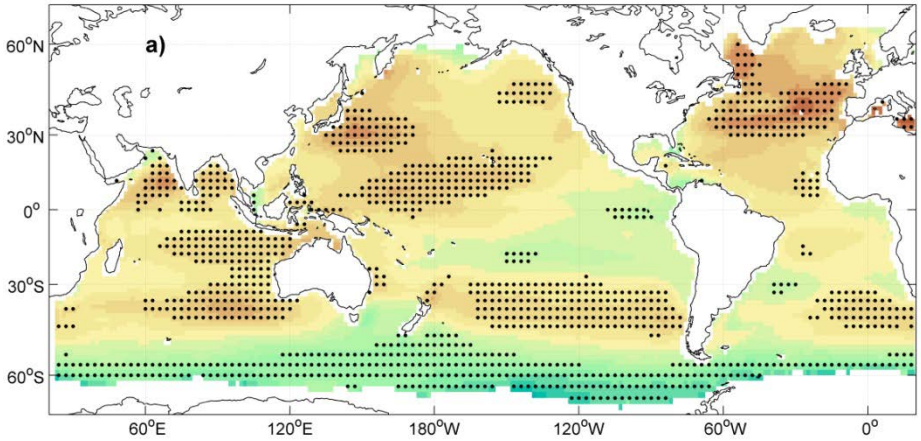


Percentage Change in H_S (RCP8.5):

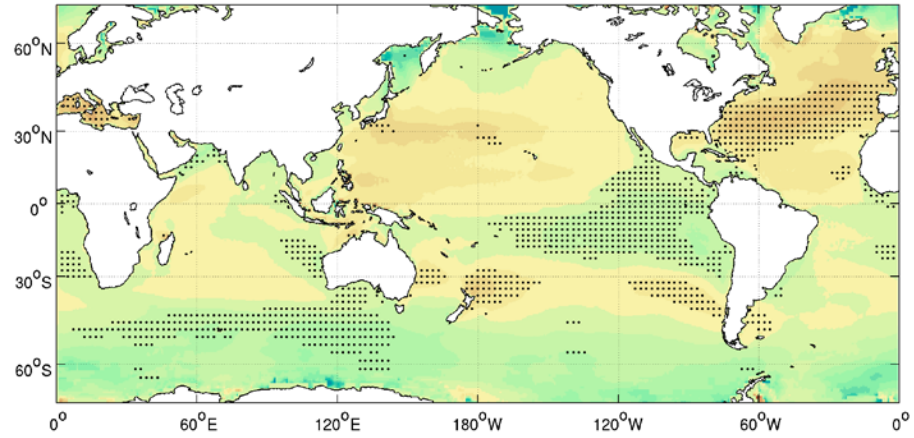
End 21st Century – Historical



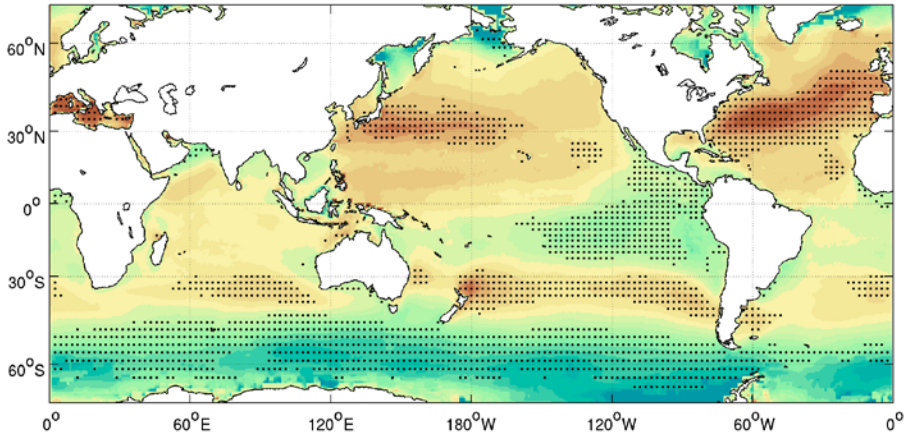
COWCLIP-1

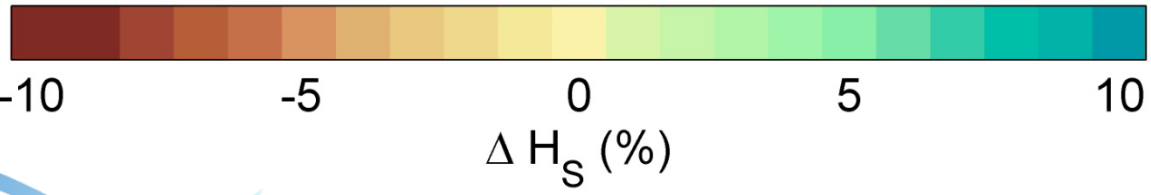


COWCLIP-2: RCP45



COWCLIP-2: RCP85





... $\Delta_t > \sigma_e$

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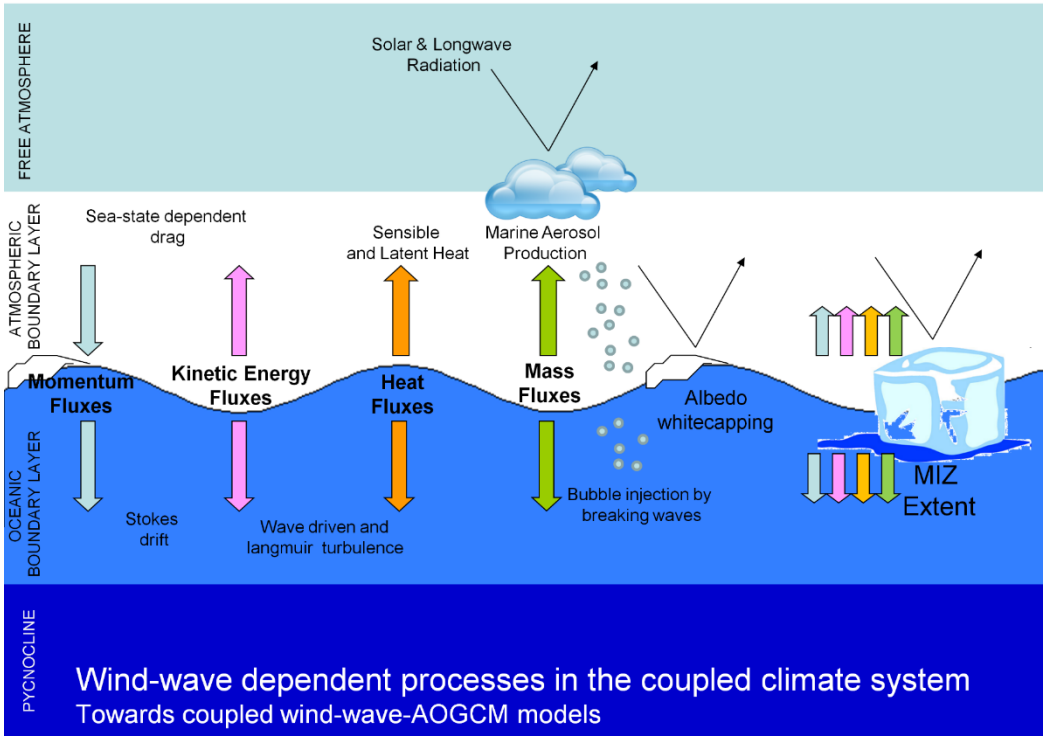
Wave – GCM Coupling Studies

Several groups developing coupled AOGCM-Wave models.



Cavaleri et al., 2012

Focus has been on wave-driven surface ocean mixing.

e.g.,

- NCAR-Brown-Utokyo CESM (CMIP6 simulations all wave-coupled)
- China FIO
- GFDL

Other processes being investigated

- CSIRO / Uni Adelaide
- Kyoto University

Wave – GCM Coupling Studies

- Studies are focussed on scientific question as to whether parameterisation of wave dependent processes can improve model skill.
- Agreed no CMIP endorsed COWCLIP MIP for CMIP6, owing to little overlap, and relative immaturity of studies

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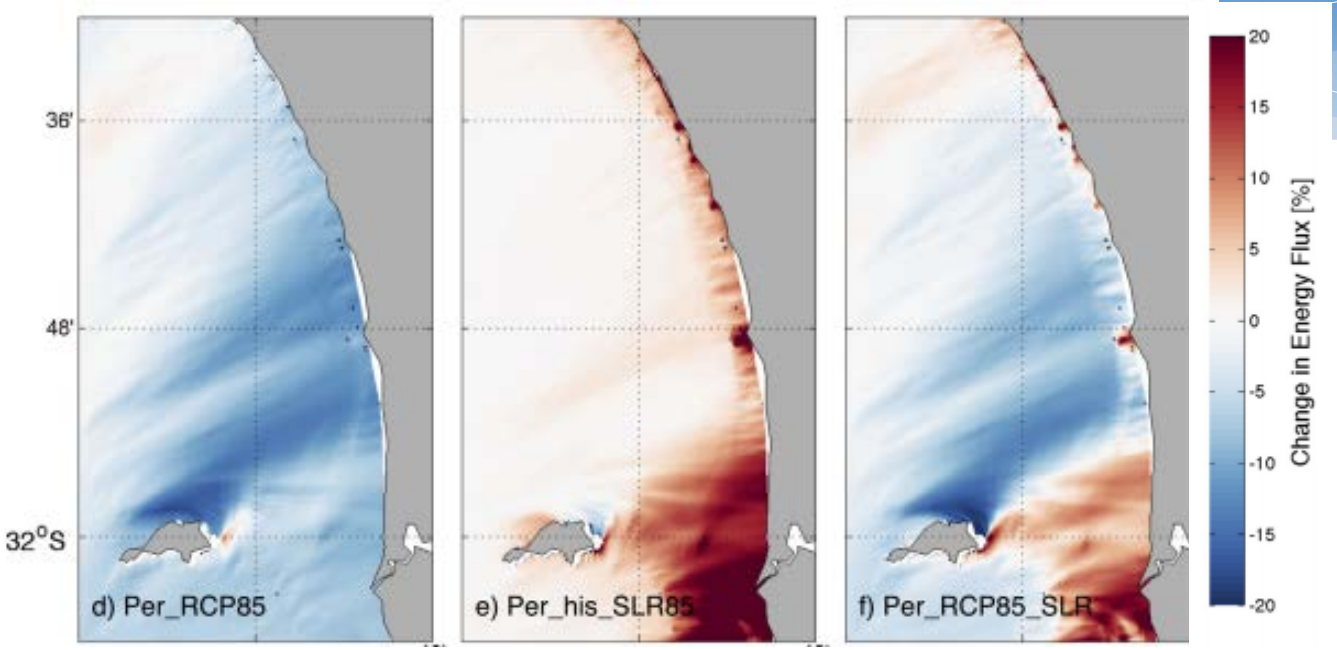
Wave – Surge - Sea-level feedbacks



- Feedbacks between sea-level, waves and storm-surges. Coastal wave field shown to be more strongly altered by sea-level than meteorological changes (e.g., Wandres et al., 2017; Arns et al., 2017).
- Integrated assessments of coastal sea-level (SLR, Waves and Storm-Surge) are necessary.

COWCliP Souvenirs

- Climate resilient coasts and offshore infrastructure require consideration of variability and change of characteristics of wind-waves
- Production of a consistent, reliable record characterising spatial and temporal variability of the global wave climate should be a priority
- Wind-waves respond to climatological forcing, but uncertainties associated with projected changes are large. Wave downscaling methodology is an important component of this uncertainty
- Many studies projecting regional and global wave climate change now available for intercomparison/assessment. Phase 2 COWCLIP intercomparisons are underway – timeline for IPCC
- The coupled atmosphere-ocean climate system is sensitive to a range of wave dependent processes. Development of coupled wave-AOGCM's continues.
- COWCliP has been successful in raising profile of waves as a climate variable
- Many challenges remain (e.g., integrated sea-level, surge, wave assessments)

COWCliP achievements to date

- Completion of phase-1 of COWCliP – intercomparison of the first community ensemble of global wave climate projections, documented in high profile manuscript (Hemer, Fan, Mori, Semedo and Wang, 2013, *Nature Climate Change)*
- High uptake of COWCliP outcomes into IPCC WG-1 AR5, Chapter 13 (Sea-Level Change)
- Inclusion of COWCliP into inter-sessional work-plan of JCOMM (june 2011)
- Publication of COWCliP community position manuscript, following the workshop in Geneva (Hemer, Wang, Weisse and Swail, 2012. *BAMS*).
- First COWCliP workshop, Geneva, 2011. Meeting Report – Hemer et al., (2011) JCOMM Tech Report 55.
- Publication of a Waves in Shallow Environments (WISE) / Working Group on Coupled Modelling (WGCM) / COWCliP community paper on role of waves in the coupled climate system (Cavaleri, Fox-Kemper and Hemer, 2012, *BAMS*)
- Commenced compilation of a second phase COWCliP ensemble of wave climate projections. Contributions from CSIRO, Environment Canada, UKMO and USGS being analysed. Other contributions anticipated.
- Open availability of global wave climate projections via web (COWCliP wiki)
- COWCliP review meeting held in Banff, Nov 2013.
- Review Meeting Report - Hemer et al. (2014a). JCOMM Tech Report 76.
- Third COWCliP workshop held in Paris, Oct 2014. Workshop Report – Hemer et al. (2014b). JCOMM Tech Report 82.
- Fourth COWCliP workshop held in Paris, Sep 2015. Wang et al. (2016a). JCOMM Tech Report 88
- Fifth COWCLiP meeting held at EGU, Vienna 2016. Wang et al. (2016b). JCOMM Tech Report 89
- **Sixth COWCLiP meeting scheduled for September 16, 2017, Liverpool UK**.

Any questions: Mark.Hemer@csiro.au