Robustness and uncertainties in global multivariate wind-wave climate projections

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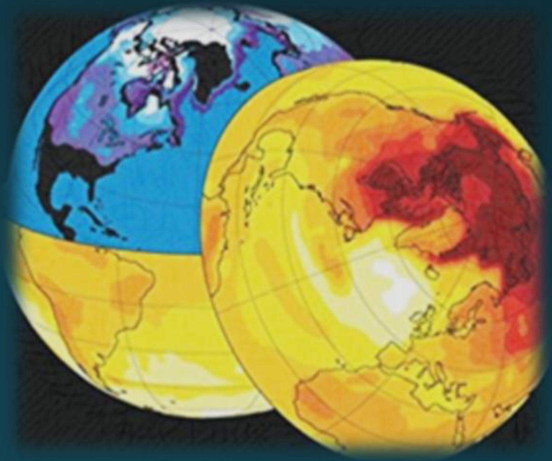
Topics

1. Global wave projections
2. COWCLIP published data
3. Ongoing COWCLIP research

COWCLIP Ocean Wave Climate

1. Global wave projections



Why are wind-waves important?

Coastal climate Impact and adaptation assessments and planning require consideration of a range of different sea-level drivers: mean changes, surges and **waves**.

Wave-driven flooding

Shoreline position change

WCRP Sea-Level 2017 Conference Statement, Aug 2017

Wind-waves in a warmer world?

Wind-waves will respond to variability and climate-driven changes in atmospheric circulation

Changing storm tracks/strength will drive changes in global wave fields (height, frequency and direction)

with potential

- geophysical (e.g. flooding, erosion)

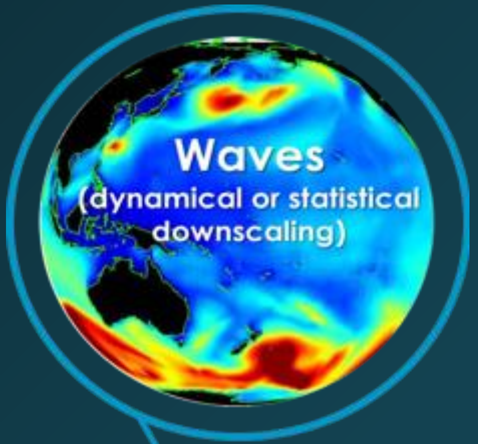
- socio-economic (e.g. infrastructure damage)

- environmental (e.g. marsh erosion, saltwater intrusion)

consequences...

How waves are derived from GCM atmospheric fields?

Wind-wave modeling methodology



Inter-scenario uncertainty (RCP25...RCP85)
Inter-model uncertainty (model forcing)
Intra-model uncertainty (realization)

Dynamical

Model (WAM, WW3)
Source Term (ST2-ST6)
Calibration(e.g., wave growth)
Resolution (spectral, numerical)
Input (sea Ice, bathymetry)

Statistical

Model (regressions, weather types)
Atmospheric fields (e.g., ERAI)
Calibration (e.g., satellite)
Bias correction

Increasing uncertainty

However, our current understanding is limited...

To date, Independent global wave projection analysis have,

1) narrow sampling of uncertainty space
(Morim et al. 2018, Global and Planetary Change)

2) little sample space overlap leading to large unquantifiable uncertainty
(Hemer et al. 2012, BAMS, Hemer et al. 2013, Nature Climate Change)

3) lack of scientific consensus with other published global wave projections across many ocean regions
(Morim et al. 2018, Global and Planetary Change)

4) provided a limited understanding of robustness
(Hemer et al. 2012, BAMS, Morim et al. 2018, Global and Planetary Change)

So, how robust are global wave projections? and which uncertainty sources dominate?

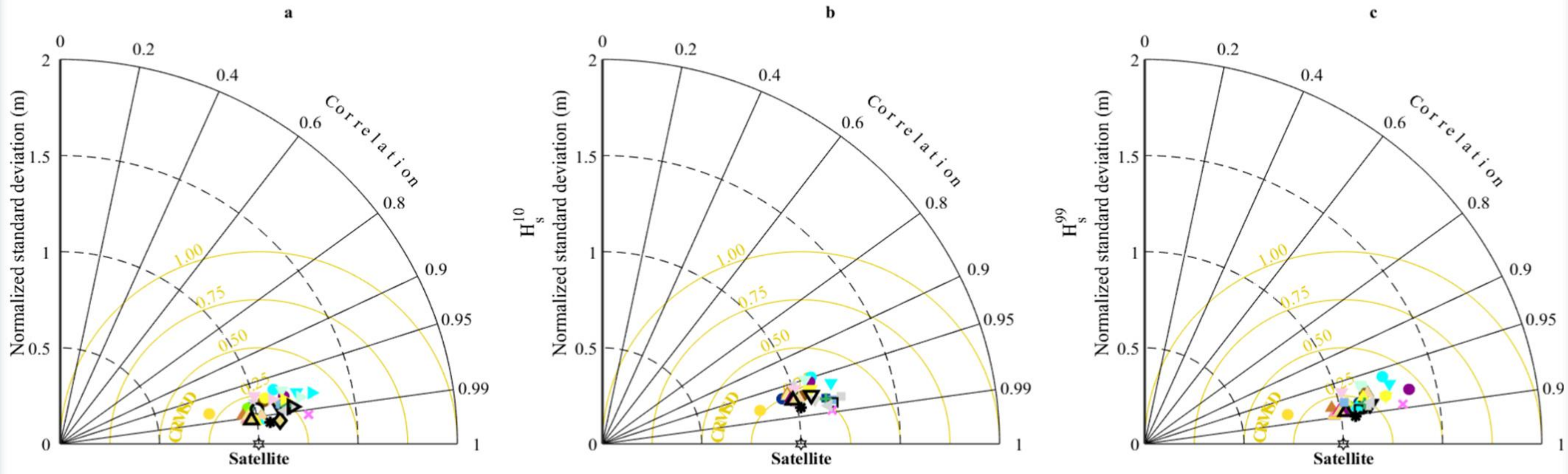
To answer, we use a large community ensemble established under a pre-designed framework...

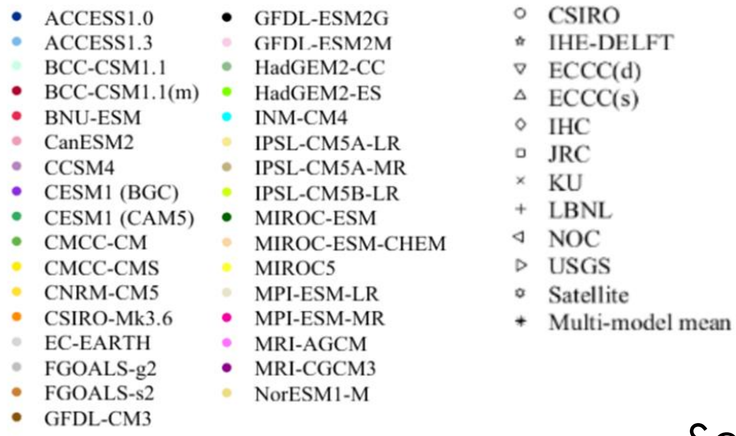
The ensemble members are obtained from ten CMIP5-based standalone data sets developed by different climate modelling centers

Community ensemble of 148 members of global multivariate wave climate projections

(10 Methods, 37 GCM forcing, 2 RCP scenarios)

Comparison of simulated wave height against satellite data (26 years)



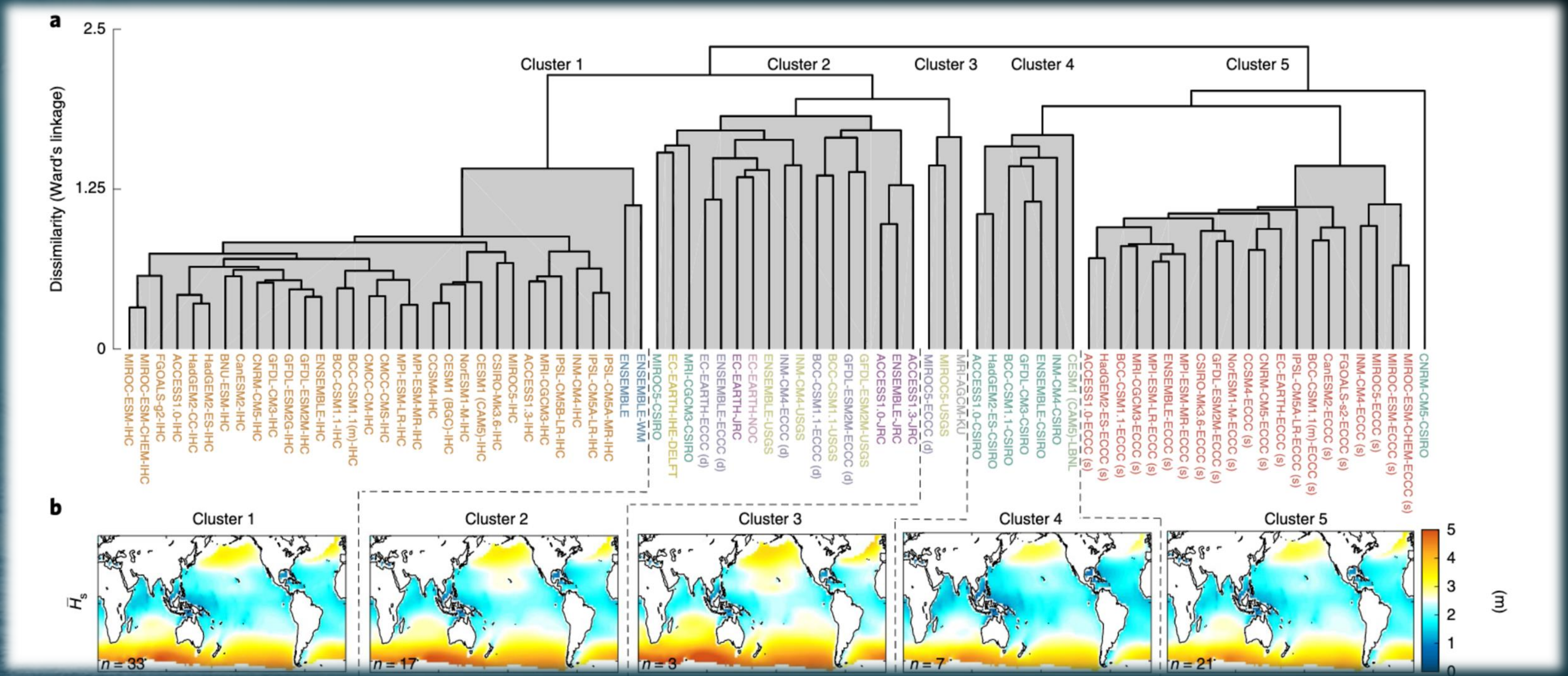


- We also performed seasonal and regional comparisons

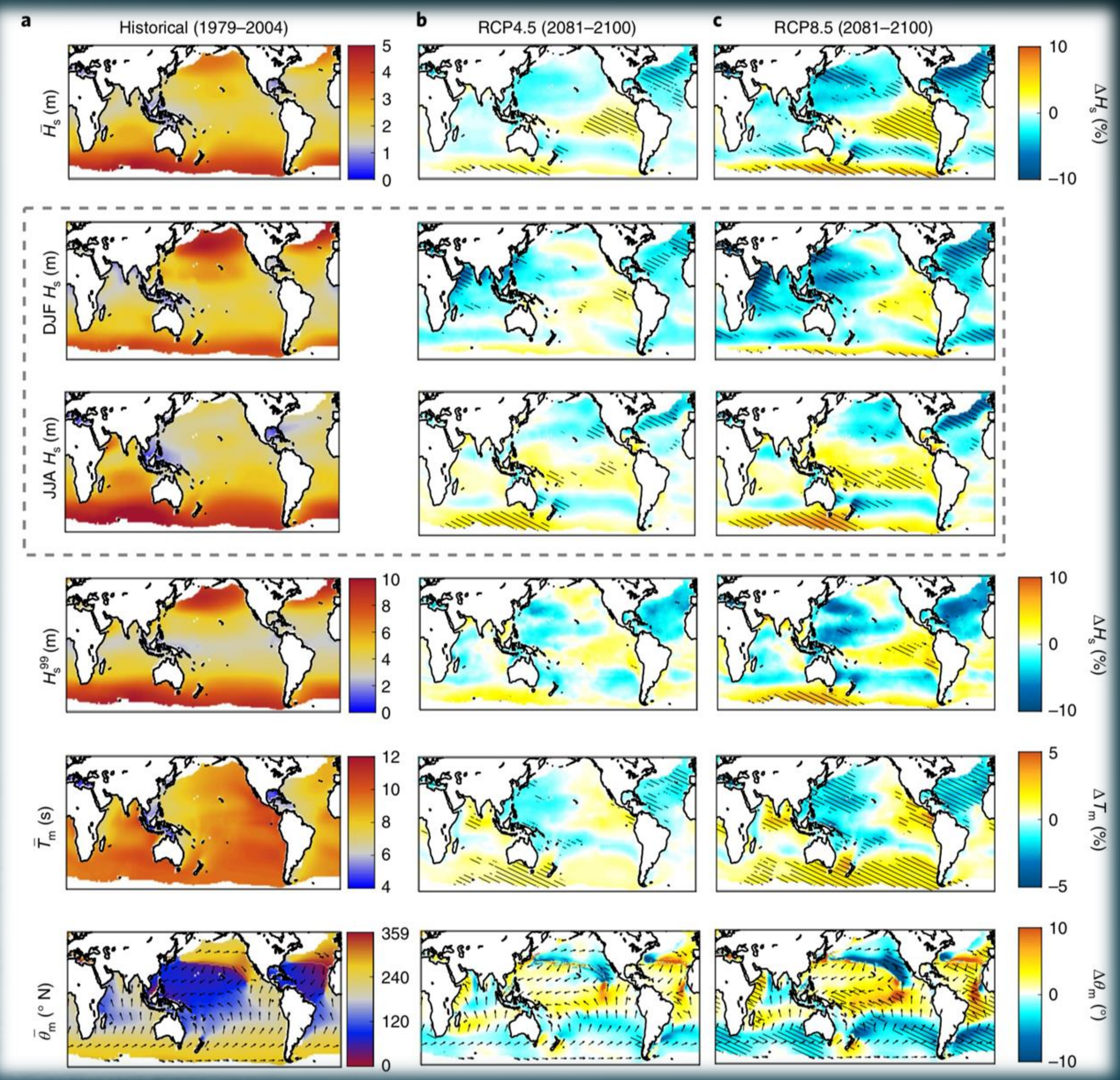
- We also performed comparison against wave reanalysis (wave period and direction)

Satellite source: Ribal and Young 2019, Scientific Data

Overall, members cluster by wave modelling method (historical)1981-2005



How much change by end of 21st century?



Weighted (by forcing) multi-member mean change

Robustness measure following IPCC (AR5) - considers:

Statistical significance

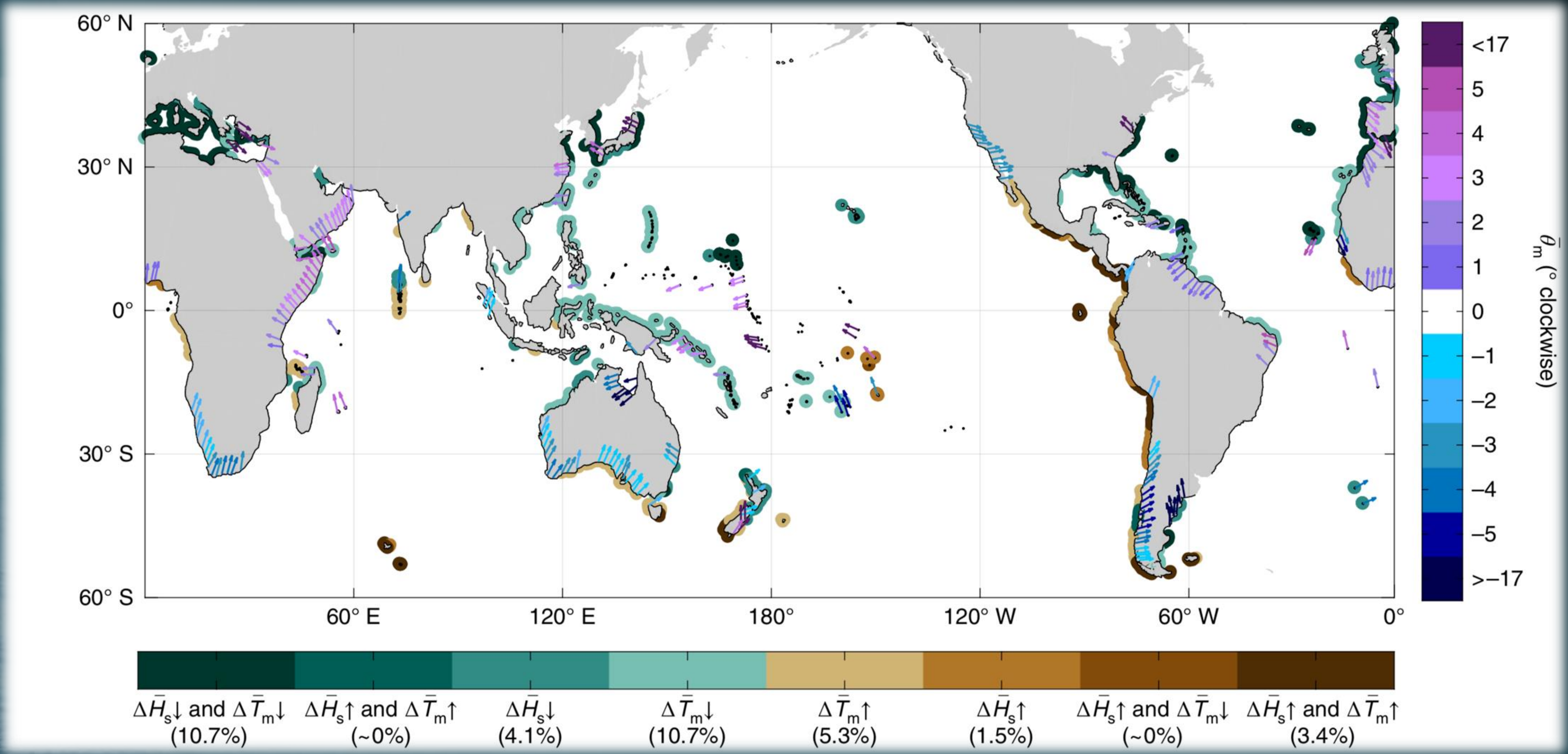
(5% level)

Agreement between significant members

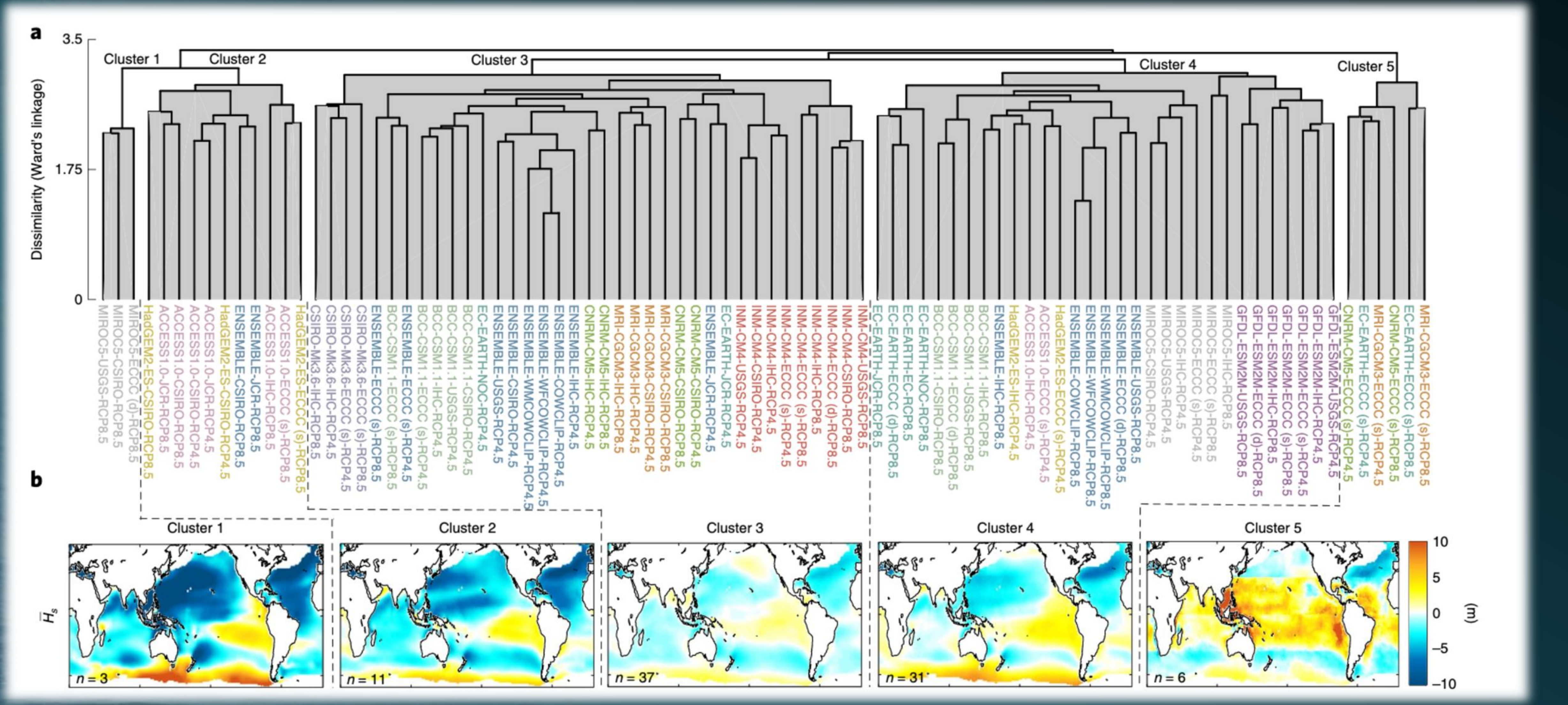
(90% level)

IPCC AR5, Tebaldi et al. 2011, GRL

~50% of coastline exhibits robust changes in forcing wave height, wave period or direction



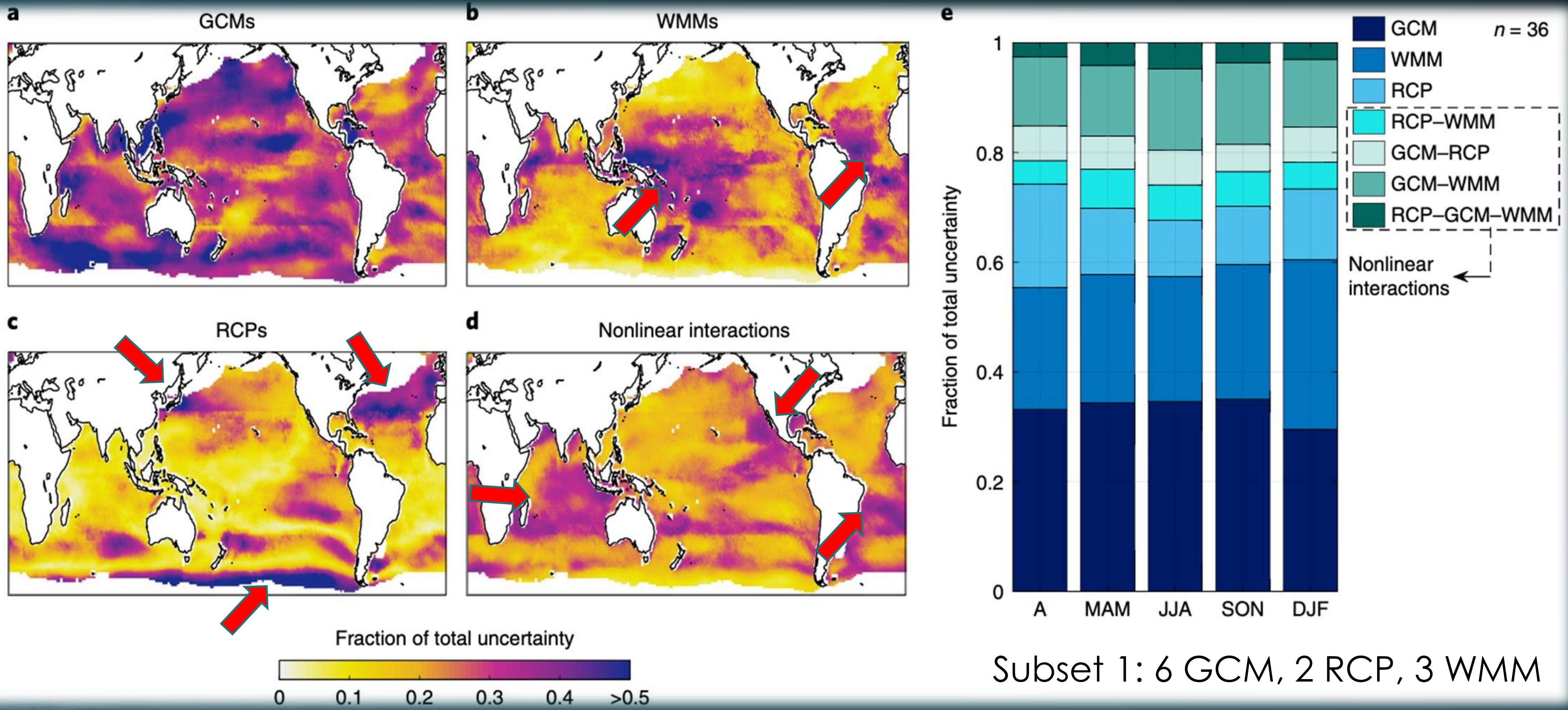
Overall, members cluster by model forcing (climate signal) 2081-2100 relative to 1981-2004



What contributes most to total uncertainty?

Multi-factor ANOVA-based decomposition with a subsampling scheme

No source of uncertainty can be neglected..



Subset 1: 6 GCM, 2 RCP, 3 WMM

We now know...

1) magnitude and robustness of wave climate signal (height, period and direction)

2) magnitude of uncertainty associated with global wave projections

3) contribution of each uncertainty to total uncertainty over globe

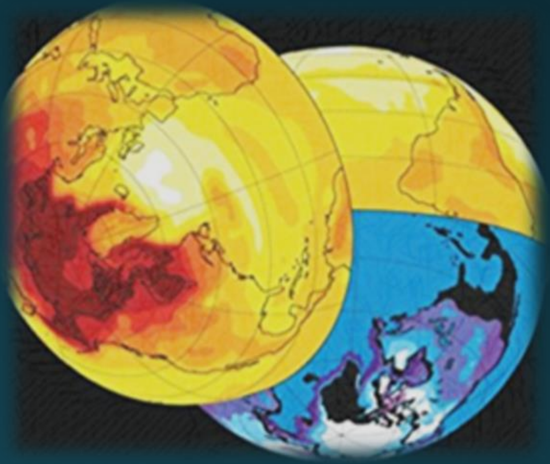
4) single-method ensembles neglect ~50% of total uncertainty

But, we still do not know

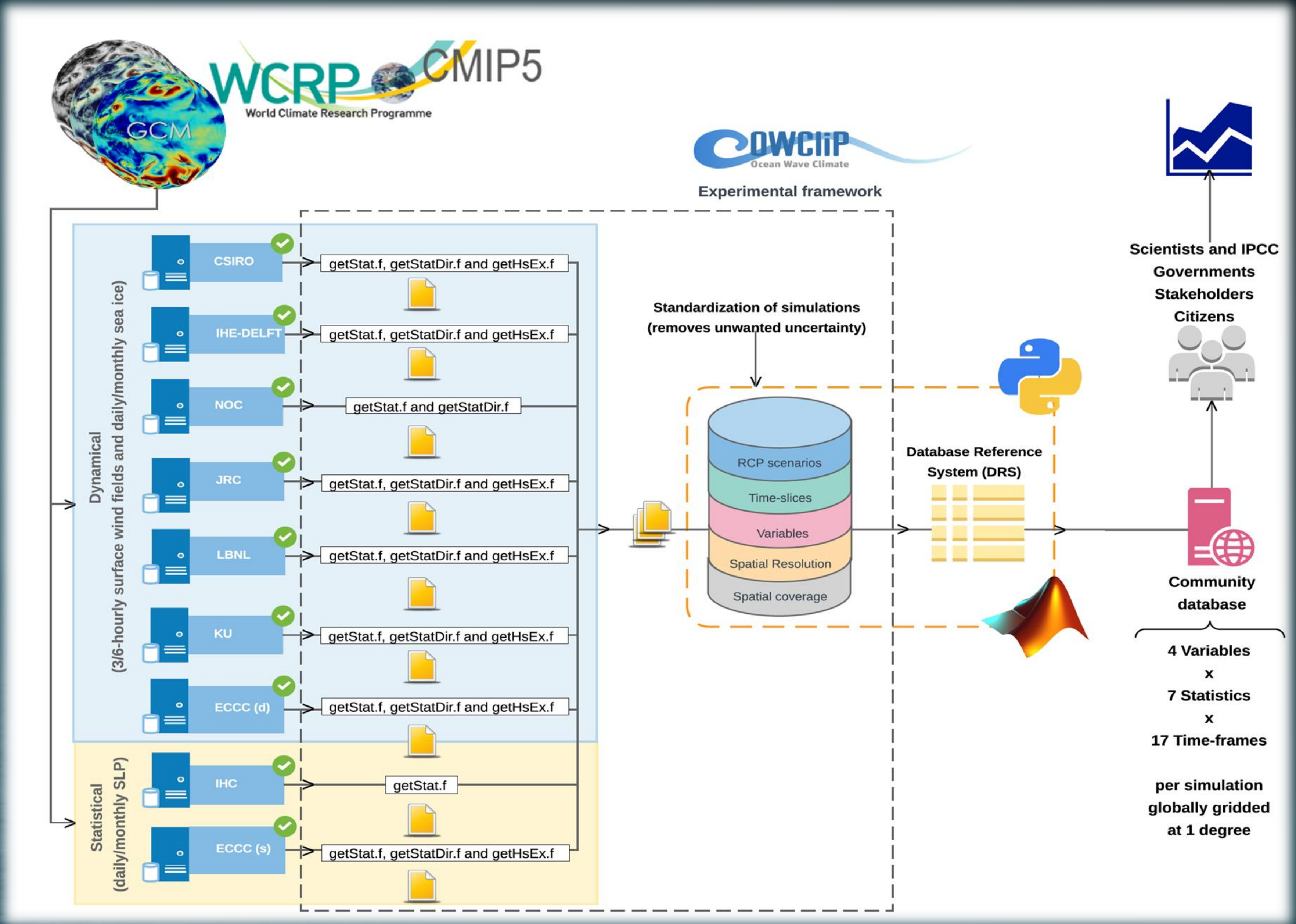
1) how much uncertainty is associated to atmospheric downscaling

2) how morphological-driven climate changes (e.g., SLR) compare to atmospheric-driven climate changes (e.g., changes in atmospheric circulation)

2. COWCLIP published data



COWCLIP Standardized data



COWCLIP2.0 data (155 simulations available)

1) Globally consistent dataset at 1 degree resolution

2) NETCDF and Metadata compliant, and consistent with CMIP5 DRS

2) 3 time-frames (monthly, seasonally, annually) from original sub-daily data

3) 7 Statistics of wave height and period and 2 statistics of wave direction

Covering...

1) 2 RCP scenarios (RCP4.5 and RCP8.5)

2) 30 GCM forcing (ACCESS1.0, ACCESS1.3, …)

3) Time-slice (1981-2004 and 2081-2100)

COWCLIP2.0: access to date remotely

OPENDAP protocol from:

http://thredds.aodn.org.au/thredds/catalog/CSIRO/Climatology/COWCLIP2/catalog.html

Catalog http://thredds.aodn.org.au/thredds/catalog/CSIRO/Climatology/COWCLIP2/global/catalog.html

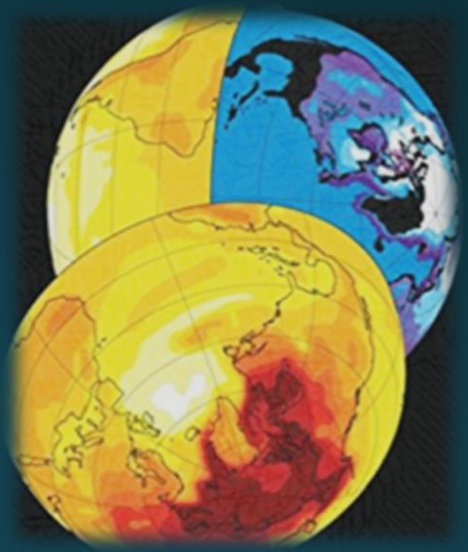
Dataset	Size	Last Modified
global		--
CSIRO/		--
DELFT-IHE/		--
ECCC-d/		--
ECCC-s/		--
IHC/		--
JRC/		--
KU/		--
LBNL/		--
NOC/		--
USGS/		--

IMOS Thredds Server at IMOS see Info
THREDDS Data Server [Version 4.42.0 - 2019-10-15T13:25:54+1100] Documentation

The data is published via the Australian Ocean Data Network (AODN)

A data descriptor has been submitted to *Scientific Data*

3. ongoing COWCLIP research



What about future annual frequency of extreme wave events?

Critical to offshore infrastructure & coastal hazard assessments

(beach recovery rate, shoreline position, wave-driven flooding)

Large waves, Nazare Portugal

1) Robust projections are key for coastal adaption

2) Accelerated sea level is continuously lowering threshold for flooding

2) Inter-annual extremes are historically linked to global climatological patterns

3) Simulations can represent high-frequency extremes better than at 'decadal-centennial' scales

Thank you!

COWCliP is a community effort

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COWCliP achievements to date

Journal publications

- Hemer, Wang, Church and Swail, 2010. Modelling proposal: Coordinated global ocean wave projections. *BAMS, 91 (4).*
- Hemer, Wang, Weisse and Swail, 2012. Advancing wind-waves climate science. *BAMS,* 93(6).
- Cavaleri, Fox-Kemper and Hemer, 2012, Wind waves in the coupled climate system. *BAMS,* 93 (11). *(Combined community paper with WISE and WGCM)*
- Hemer, Fan, Mori, Semedo and Wang, 2013, Projected changes in wave climate from a multi-model ensemble. *Nature Climate Change,* 3 (5)
- Morim, Hemer, Cartwright, Strauss and Andutta, 2018. On the concordance of 21st Century wind-wave projections. *Glob. Planetary Change,* 167.
- Morim et al., 2019. Robustness and uncertainties in global multivariate wind wave climate. *Nature Climate Change, 9 (9).*

Meetings / Technical Reports

- First COWCliP workshop, Geneva, 2011. JCOMM Tech Report 55.
- Informal COWCLiP meeting, Hawaii, 2011. Alongside Wave Workshop.
- Second COWCliP review meeting, Banff, Nov 2013. JCOMM Tech Report 76.
- Third COWCliP workshop, Paris, Oct 2014. JCOMM Tech Report 82.
- Fourth COWCliP workshop, Paris, Sep 2015. JCOMM Tech Report 88
- Fifth COWCLiP meeting, Vienna April 2016. JCOMM Tech Report 89
- Sixth COWCLiP meeting, Liverpool UK, September 16, 2017.
- Seventh COWCLiP meeting, Paris, May 2018. JCOMM Tech Report 92
- **Eighth COWCLiP meeting, Melbourne, Nov 2019.**

Other Outputs / Impacts

2011: Inclusion of COWCliP into inter-sessional work-plan of JCOMM

2013: Open availability of global wave climate projections via web (COWCliP wiki)

2013: High uptake of COWCliP outcomes into IPCC WG-1 AR5, Chapter 13 (Sea-Level Change)

2017: COWCLiP website http://www.cowclip.org

2019: Cover Story Nature Climate Change, Sep Issue.

2019: The Conversation article.

2019: High uptake of COWCliP outcomes into IPCC SROCC and AR6 WG-1 Drafts

2019: Open data publication of COWCLIP global projections database

Thank you!

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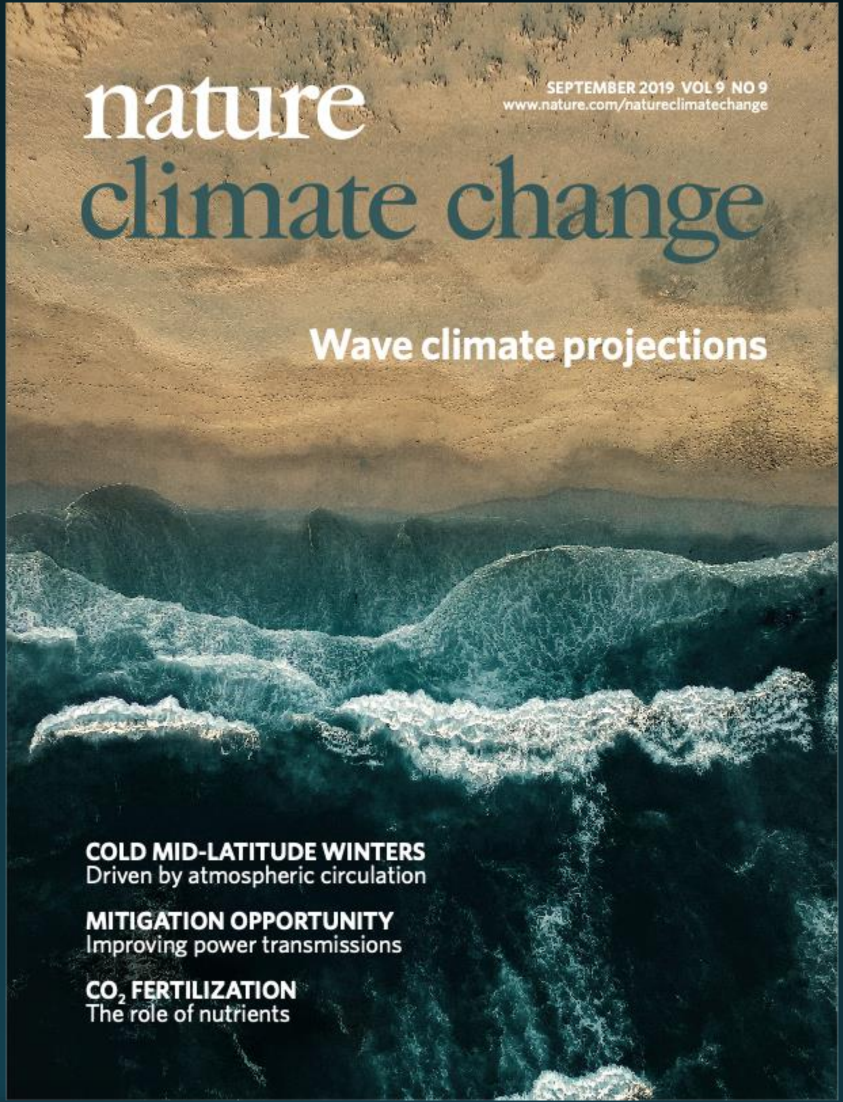
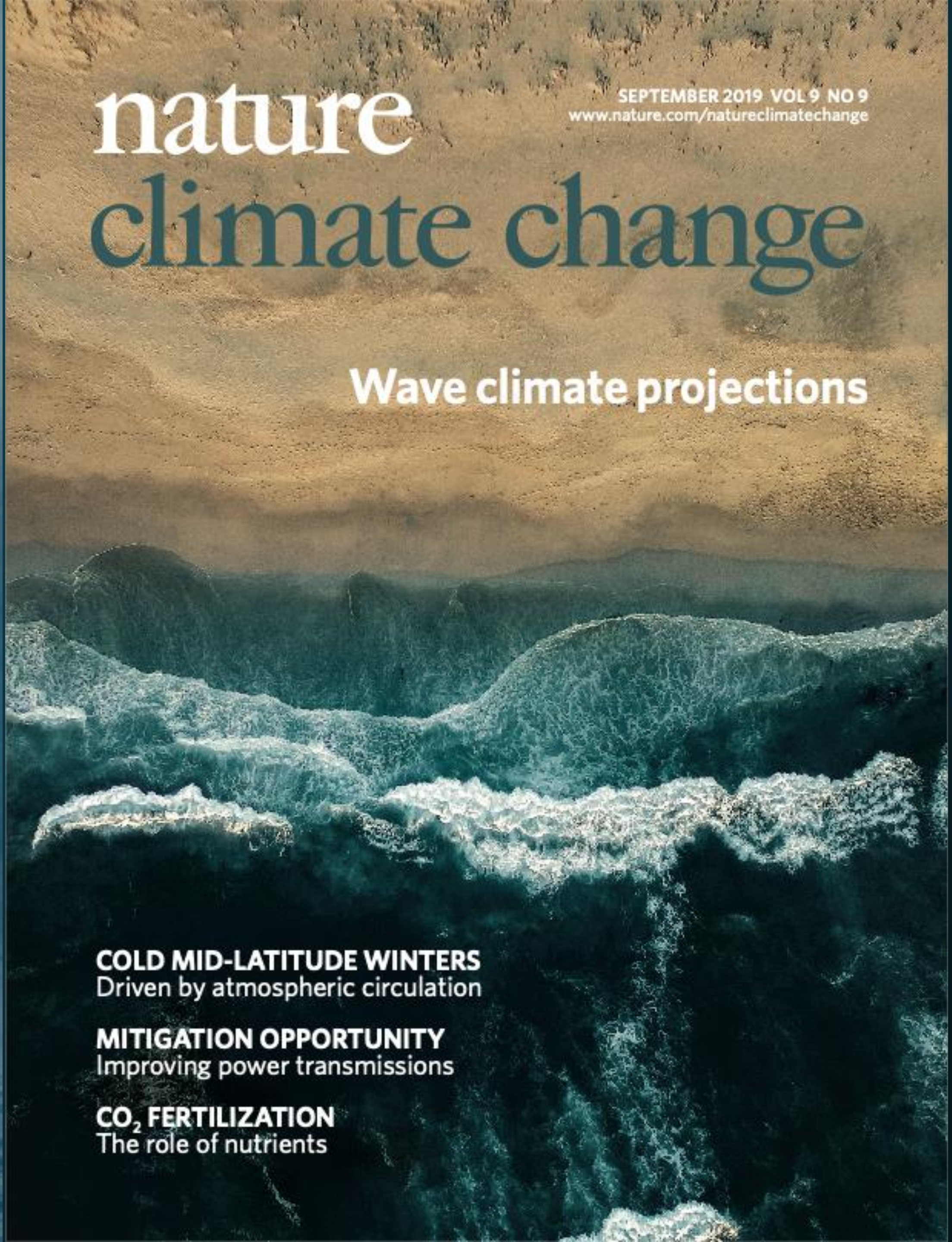


COWClip
Ocean Wave Climate



OWCliP
Ocean Wave Climate

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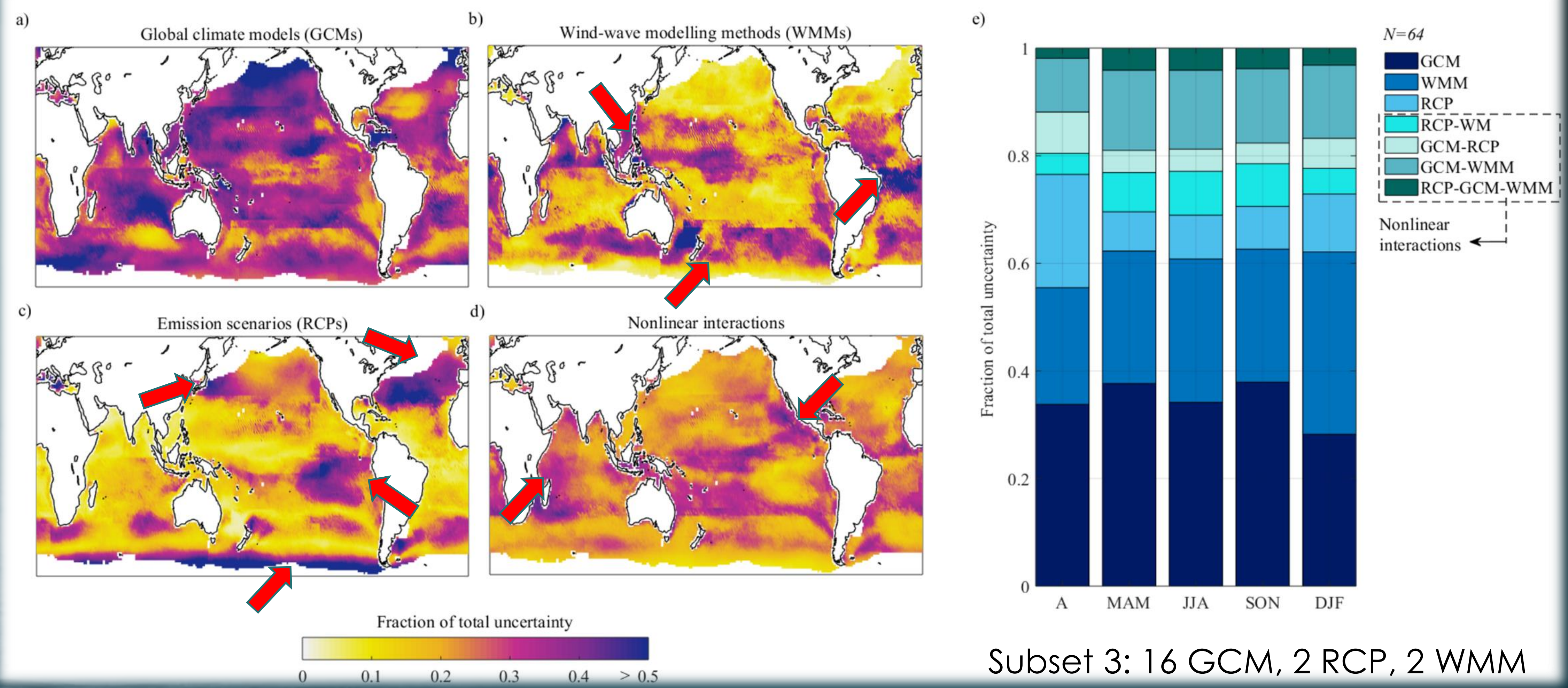

Subset 3: 16 GCM, 2 RCP, 2 WMM