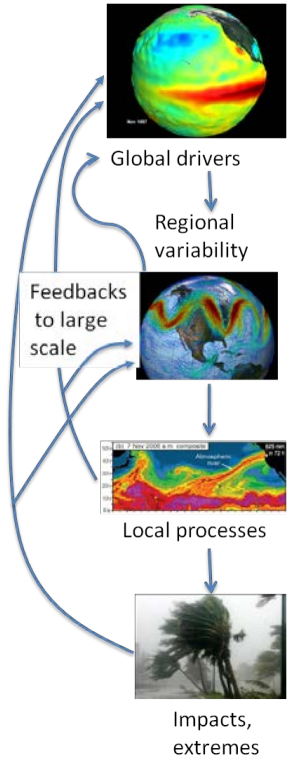
Global High Resolution Modelling

Malcolm Roberts– *Met Office, Exeter*
Pier Luigi Vidale – *NCAS-Climate, University of Reading*
Rein Haarsma – *KNMI, Utrecht, Netherlands*



- Recent highlights and future thoughts
  - Coupled simulations with eddy-rich ocean
  - Future scenario simulations from HighResMIP
  - Data availability – raw and processed outputs
  - Global simulation vs observations

With thanks Ségolène Berthou, Dian Putrasahan, Christopher Roberts, Dmitry Sein, Bjorn Stevens, Benoît Vannière,
and to all the many people involved in PRIMAVERA, HighResMIP, DYAMOND and other projects who have contributed to our current status

Co-funded by the European Union

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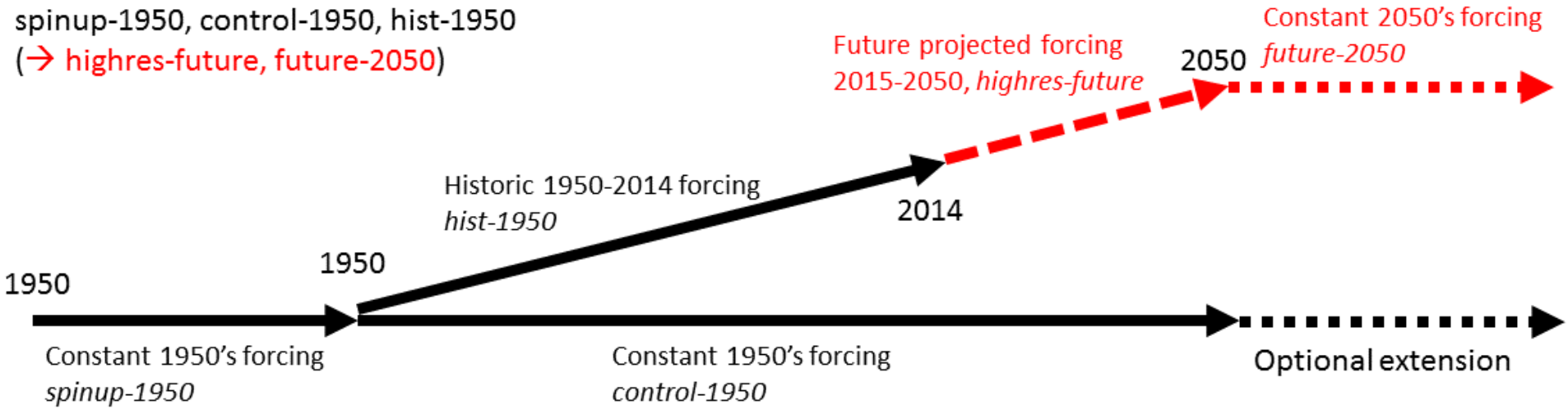
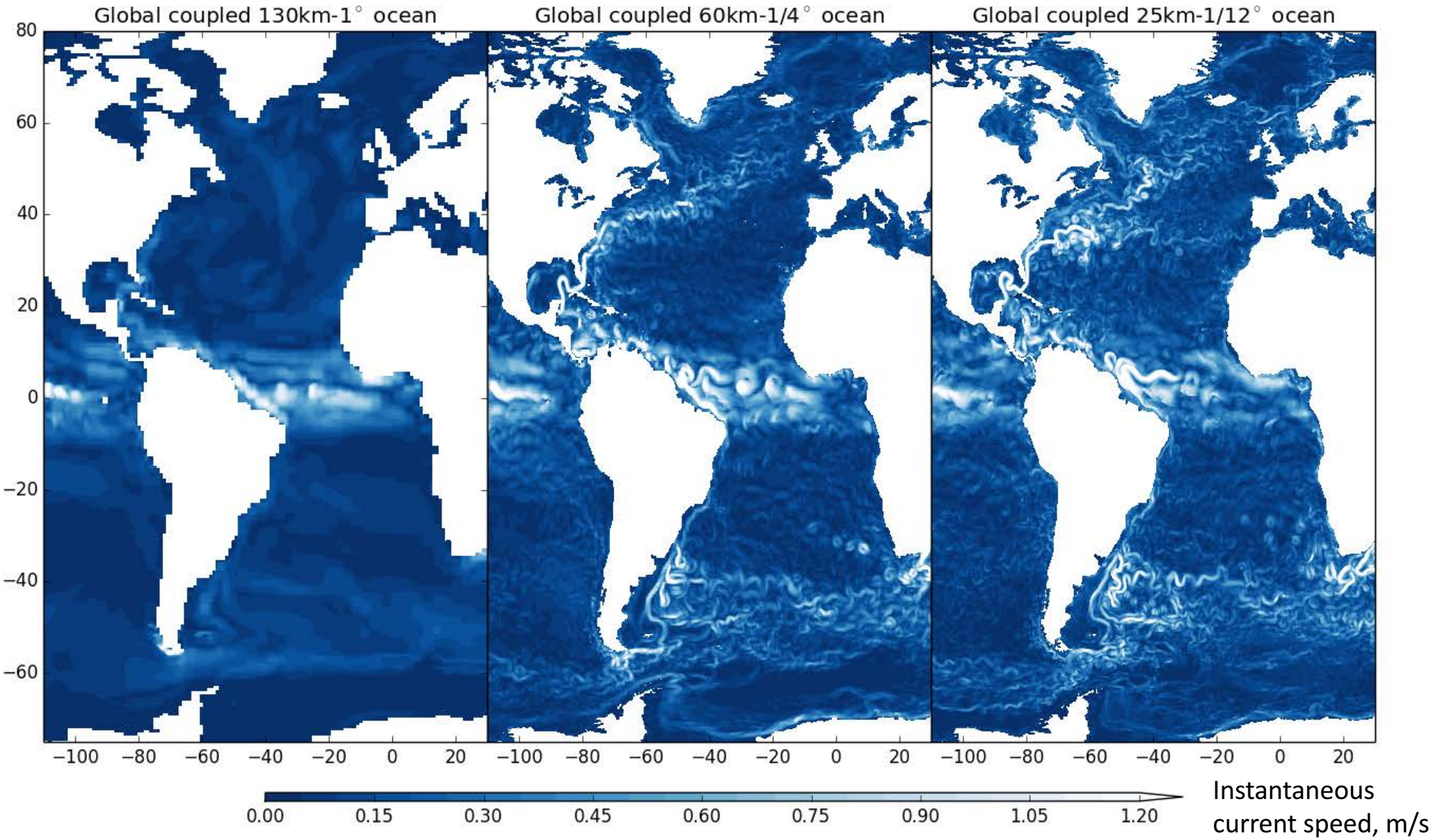
CMIP6 HighResMIP simulations

Physical model only x 2 resolutions, simplified aerosol optical properties (MACv2-SP) recommended

Atmosphere-land-only, 1950-2014 (→ 2050)
Forced by observed SST and sea-ice and historic forcings (→ projected)
highresSST-present (→ highresSST-future)

Coupled climate, 1950-2014 (→ 2050)
Forced by constant 1950 and historic forcings (→ projected)
Initial coupled spin-up period ~ 30-50 years from 1950 EN4 ocean climatology
spinup-1950, control-1950, hist-1950
(→ highres-future, future-2050)




Global coupled 130km-1° ocean
Global coupled 60km-1/4° ocean
Global coupled 25km-1/12° ocean
80
60
40
20
0
−20
−40
−60
−100 −80 −60 −40 −20 0 20
0.00 0.15 0.30 0.45 0.60 0.75 0.90 1.05 1.20
Instantaneous current speed, m/s

Institution	MOHC, UREAD, NERC	EC-Earth KNMI,SHMI, BSC, CNR	CERFACS	MPI-M	AWI	iHESP TAMU, QNLM, NCAR
Model name	HadGEM3 GC3.1	EC-Earth3P	CNRM-CM6	MPI-ESM1-2	AWI-CM 1.0	CESM
Model components	UM NEMO CICE5	IFS NEMO LIM	ARPEGE NEMO GELATO	ECHAM6.3 MPIOM1.63 MPIOM1.63	ECHAM6.3 FESOM FESIM	CAM5 POP2 CICE4
Atmos dynamical scheme (grid)	Grid point (SISL, lat-long)	Spectral (linear, reduced Gaussian)	Spectral (linear, reduced Gaussian)	Spectral (triangular, Gaussian)	Spectral (triangular, Gaussian)	Spectral element
Atmos grid name	N216, N512	Tl1279	Tl359	T127	T127	0.25
Atmos mesh spacing 0N	93, 39	16	55	104	104	28
Atmos mesh spacing 50N	60, 25	16	50	67	67	18
Atmos nominal res (CMIP6)	100, 50	25	50	100	100	25
Atmos model levels (top)	85 (85km)	91 (0.01 hPa)	91 (78.4 km)	95 (0.01 hPa)	95 (0.01 hPa)	30 (3 hPa)
Ocean grid name	ORCA	ORCA	ORCA	TP	FESOM (unstructured)	POP
Ocean nominal res (km)	8	8	8	10	10 (regionally)	10
Ocean levels	75	75	75	40	47	62

Groups who are planning or have already started HighResMIP coupled simulations with eddy-rich ocean resolution

Five PRIMAVERA groups
+
iHESP (collaboration between QNLM (China), Texas A&M and NCAR (USA), eddy-resolving coupled modelling at 3+ years per day)

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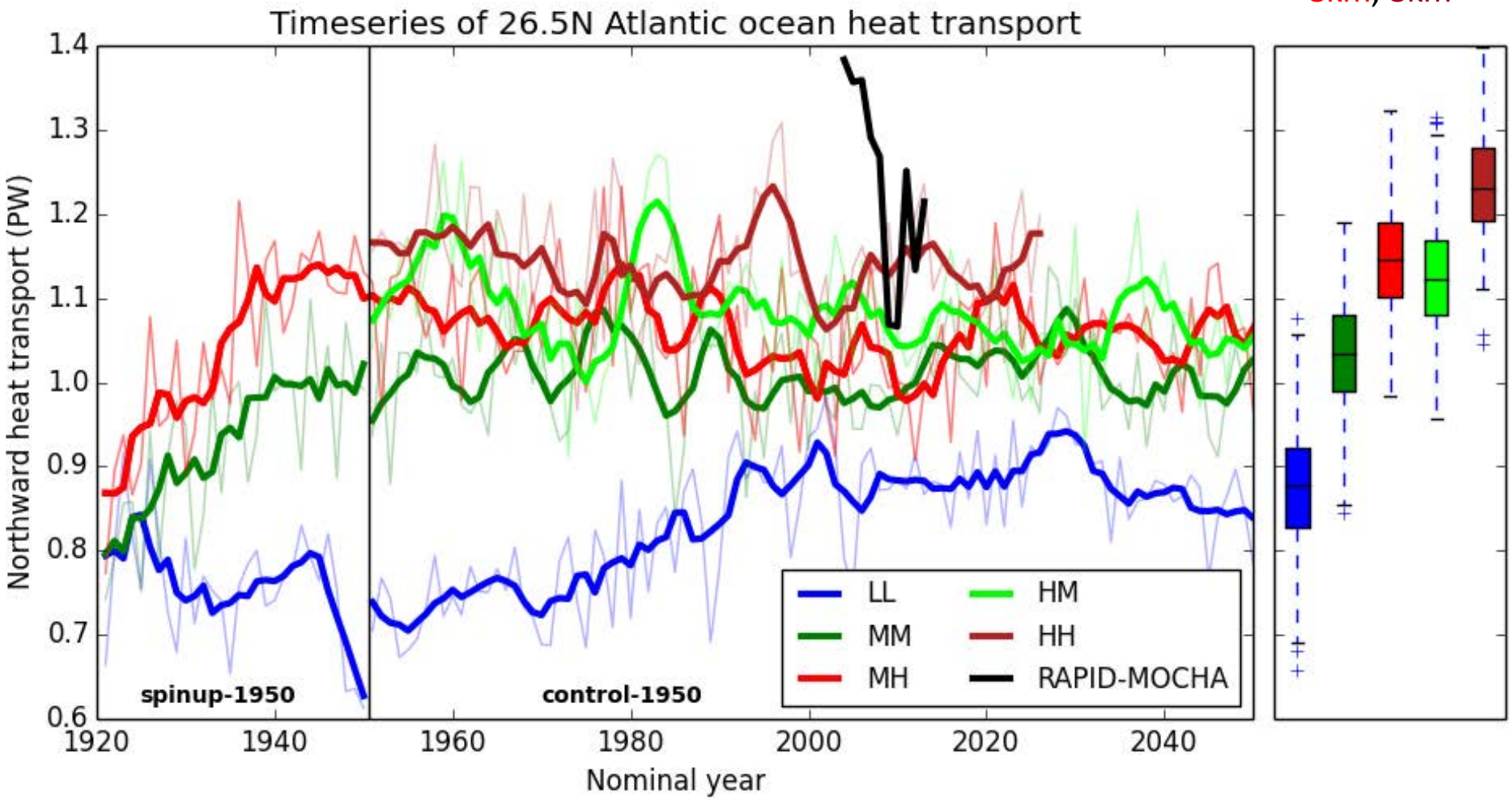
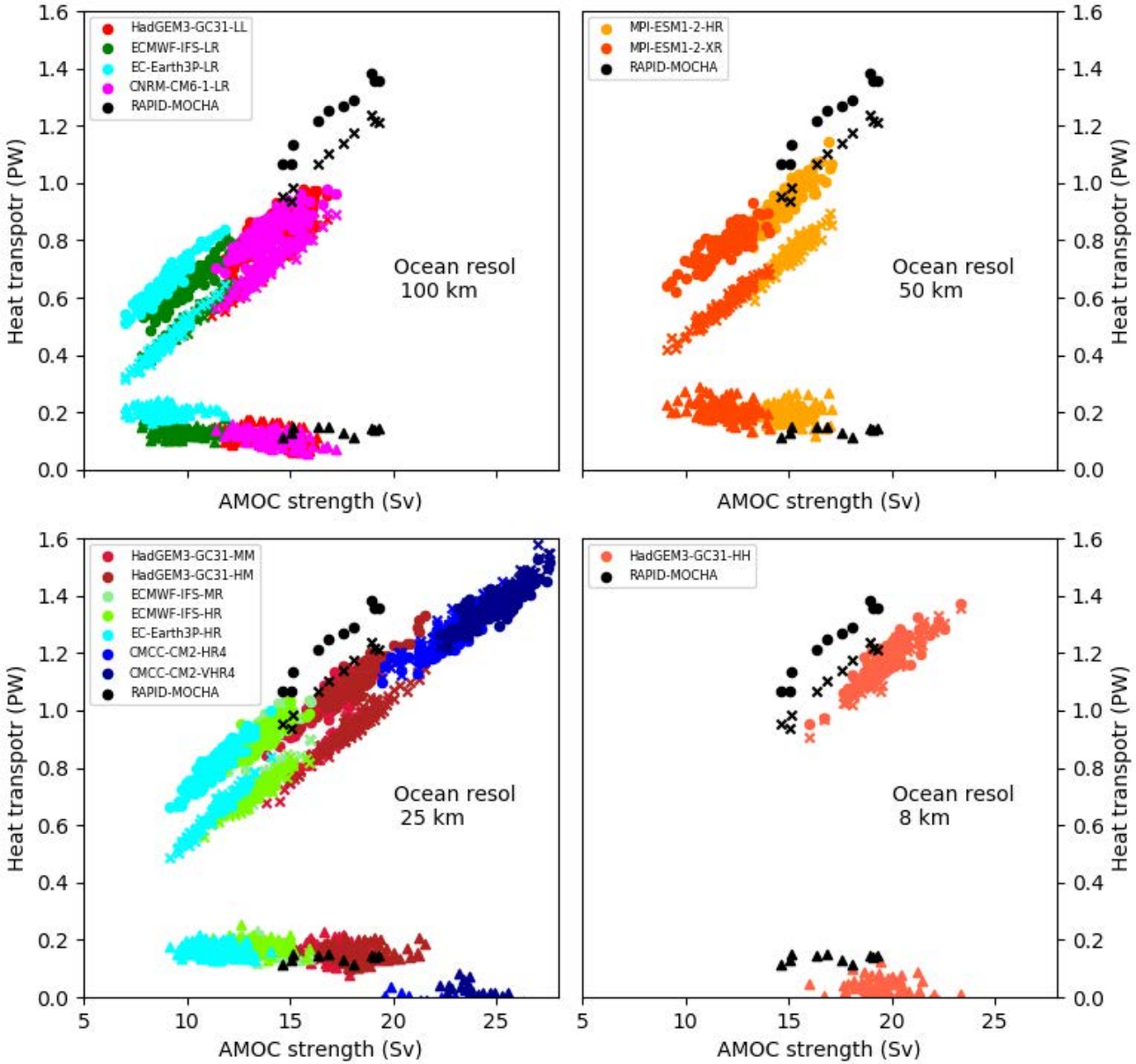
HadGEM3-GC3.1 HighResMIP control-1950

Ocean resolutions
100km
25km, 25km
8km, 8km





Scatter plots of Atlantic Meridional Overturning Circulation (AMOC) strength vs northward heat transport components at 26.5N, calculated consistent with the RAPID-MOCHA array

Wide array of behaviour, whichever resolution used

Courtesy Christopher Roberts, ECMWF

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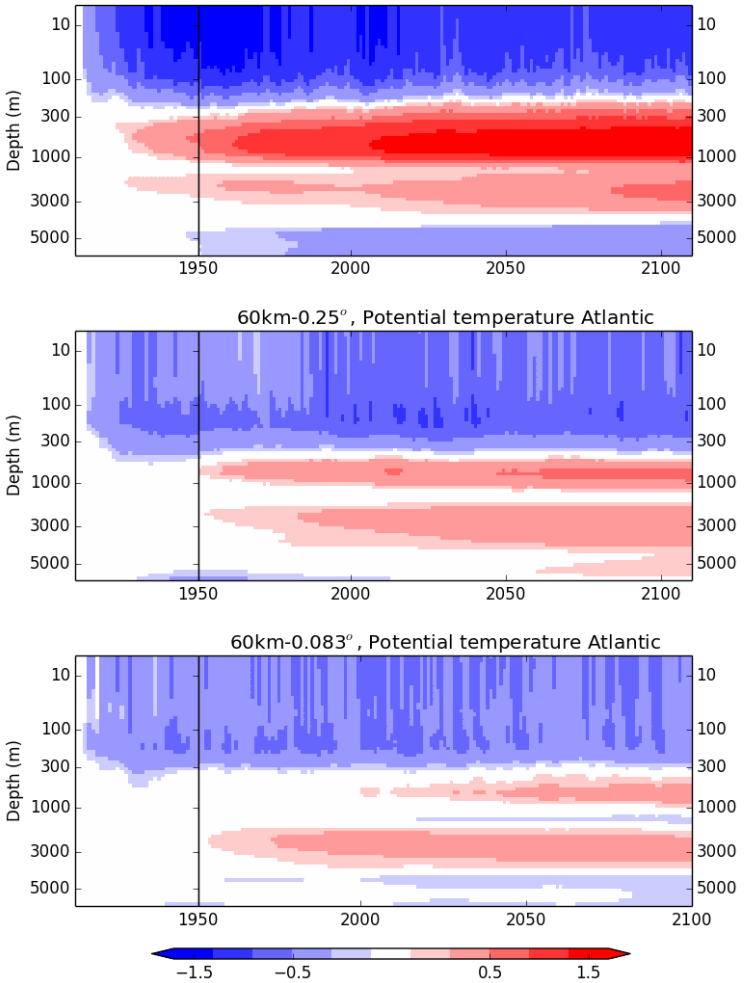
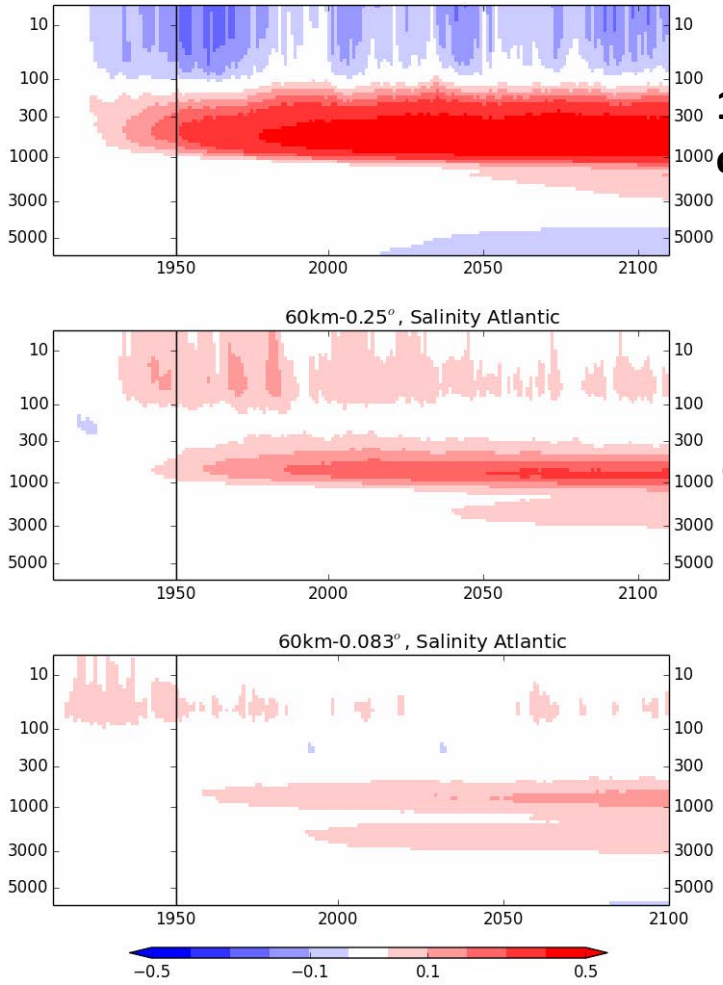
HighResMIP short spin-up protocol – what do we learn?

HadGEM3-GC3.1 HighResMIP coupled simulations at different resolutions

Potential temperature drift in Atlantic

Salinity drift in Atlantic





100km ocean

25km ocean

8km ocean

Atlantic time/depth drifts of potential temperature and salinity at 3 ocean resolutions

Just one model – interesting…

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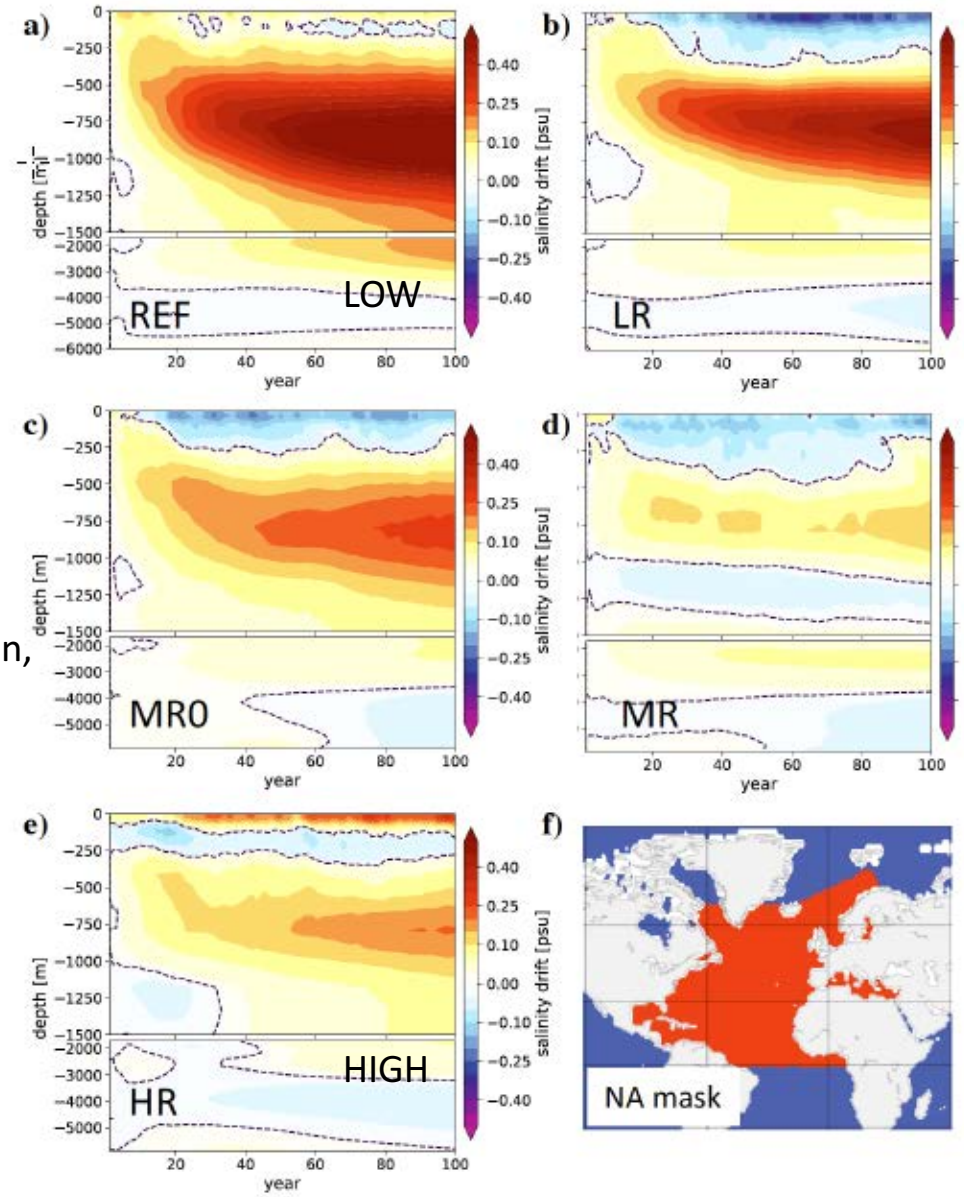
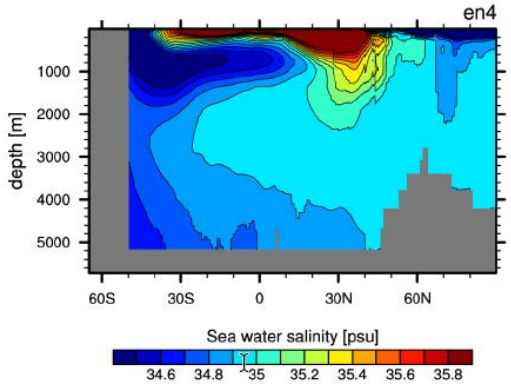
Salinity bias vs initial conditions (EN4)

AWI-CM1-1 coupled models at different resolutions (FESOM unstructured mesh)

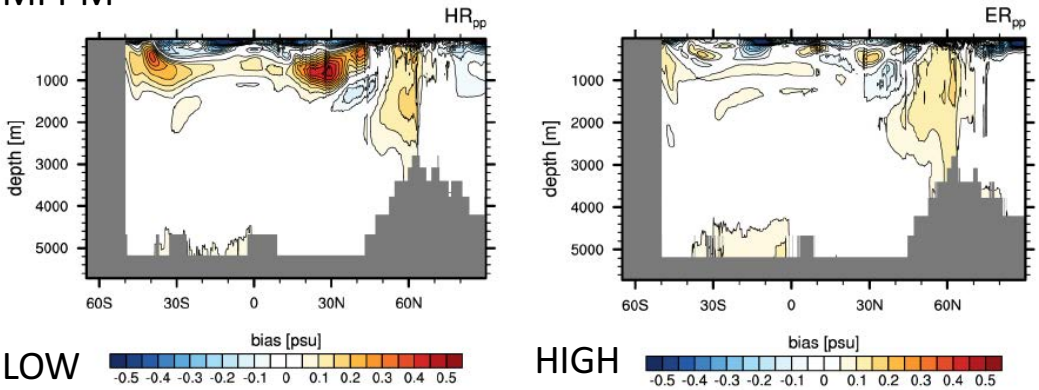


Courtesy Dmitry Sein, AWI

MPI-ESM1-2 coupled models with 0.4 and 0.1 ocean resolution



Courtesy Dian Putrasahan, MPI-M



LOW HIGH

HighResMIP future simulations

- Using only one scenario currently, out to 2050
  - SSP585

- Over the next few decades the variability is key
  - need models that can reliably represent that variability to gauge risk
  - Look at tropical cyclones (TCs) as an example

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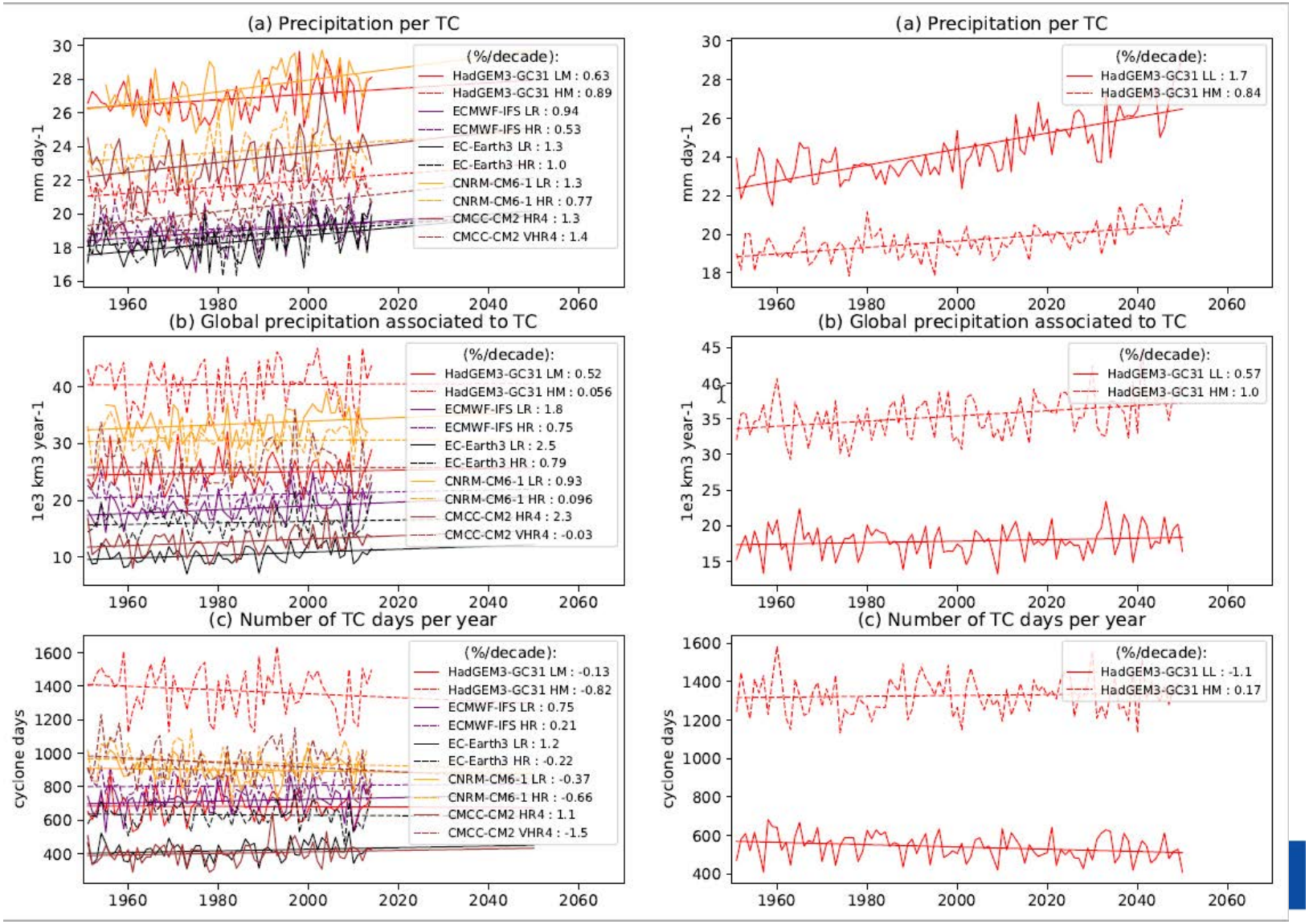
highresSST-present – **atmosphere only**

hist-1950 → highres-future - **coupled**

Benoît Vannière, NCAS-Climate, in prep



Trend in precipitation per TC seems robust in most models, and in both atmosphere-only and coupled simulations

But no great change in number of TC days per year

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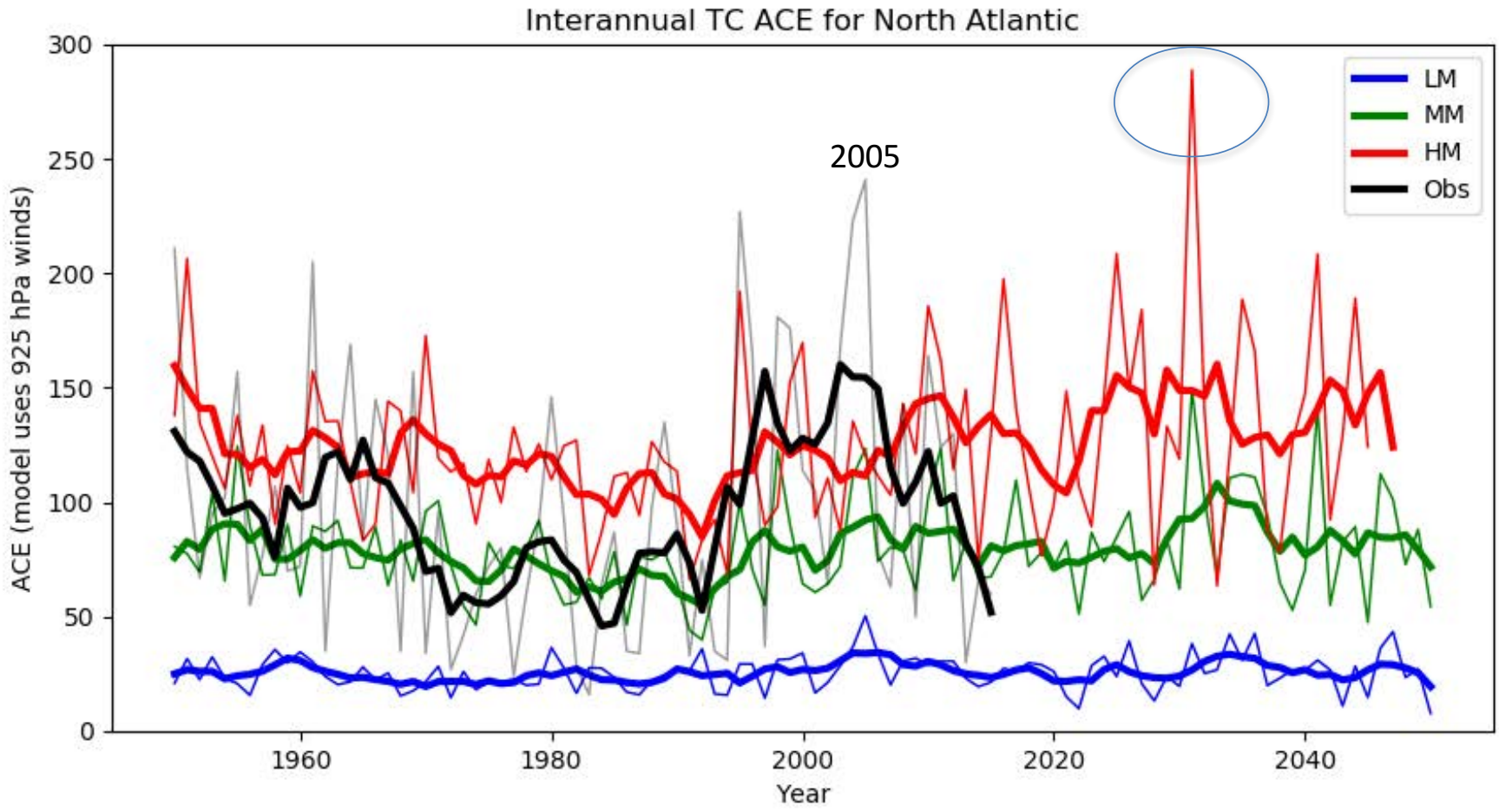
Over next few decades, variability is key for climate risk, i.e. one huge year vs slight change in mean

Mean changes vs variability
Climate extremes risk
highresSST-present → future

LM = 250km
MM = 100km
HM = 50km
(CMIP nominal)



ACE = accumulated cyclone energy = sum of square of six hourly windspeed over TC lifetime over whole season

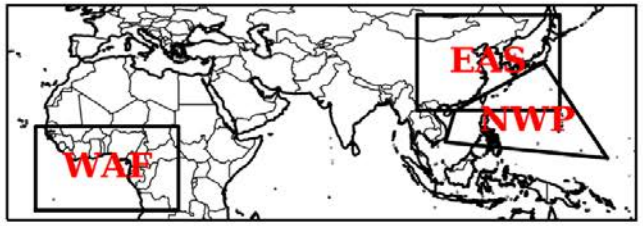
Contributions to precipitation intensities and change (2040's vs 2000's) at different model resolutions

250 km resolution (CMIP6 nominal resolution)

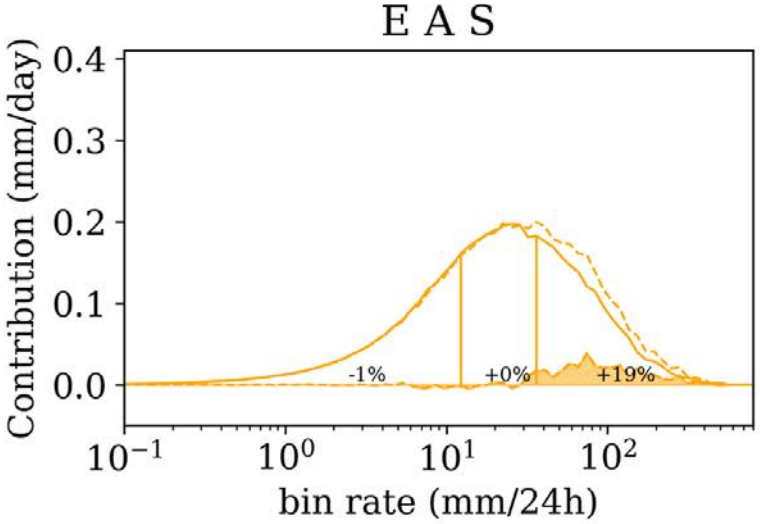
Courtesy Ségolène Berthou, Met Office

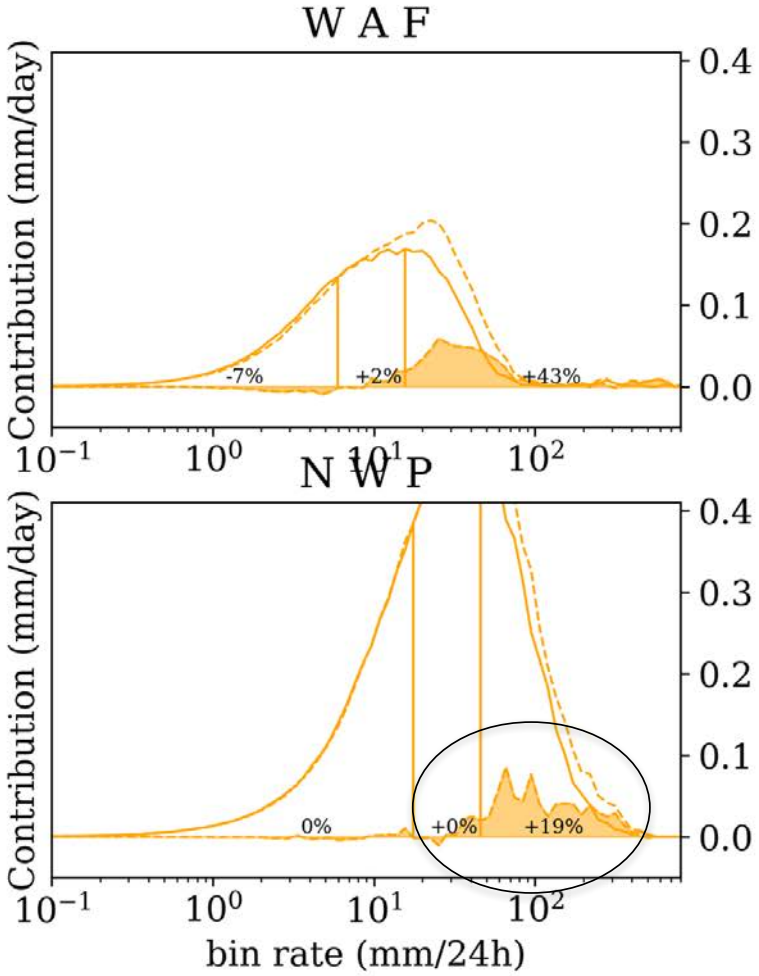
20% Increase in Eastern Asia high rates at low resolution
Increase in high intensities in North-West Pacific

Low resolution (~160km)
July to September



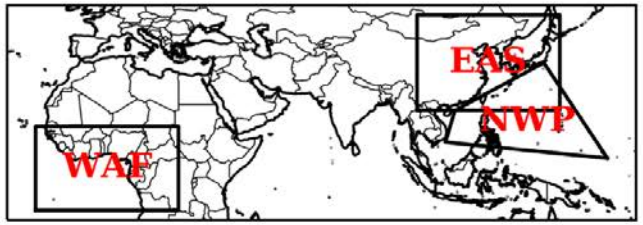
In West Africa, although present-day distributions are different between resolutions, future changes are similar



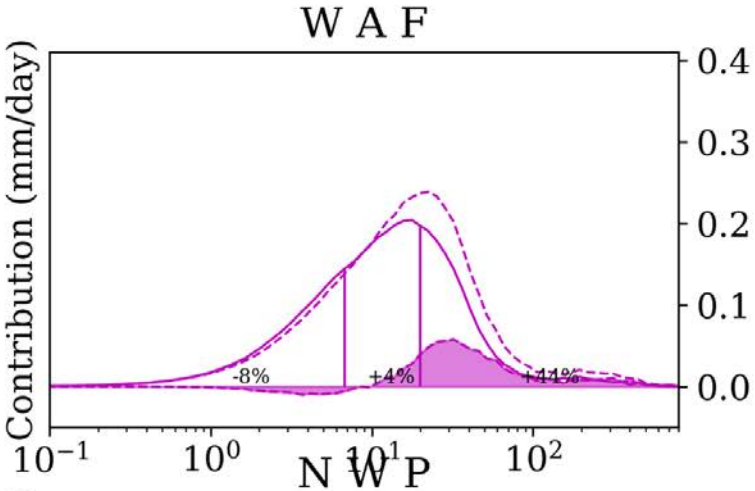


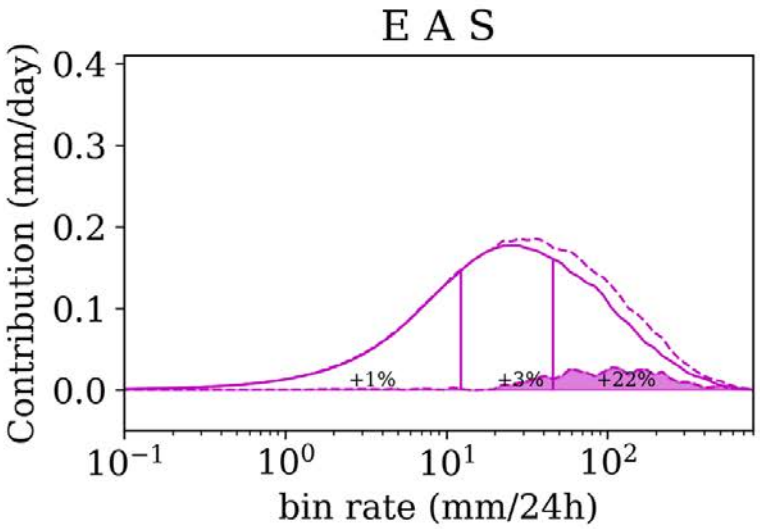
100 km resolution (CMIP6 nominal resolution)

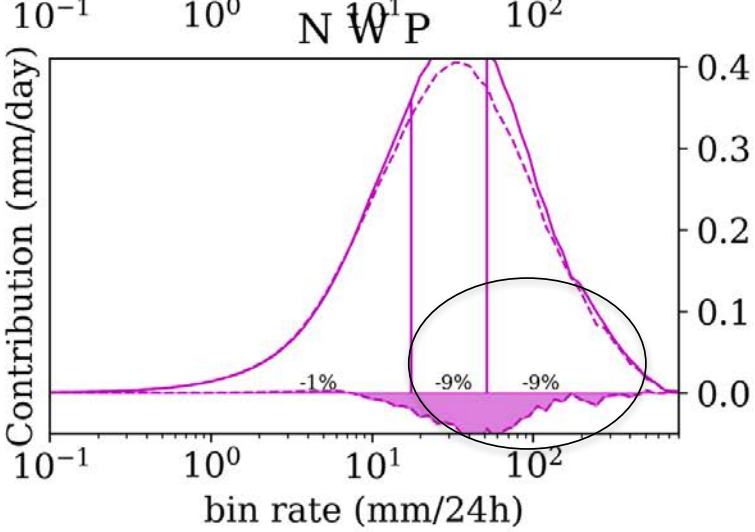
Medium resolution (~60km)
July to September



In West Africa, although present-day distributions are different between resolutions, future changes are similar



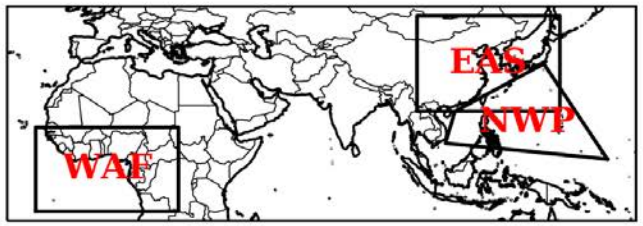




20% Increase in Eastern Asia high rates at medium resolution
Mostly decrease in medium intensities in North-West Pacific

50 km resolution (CMIP6 nominal resolution)

High resolution (~25km)
July to September



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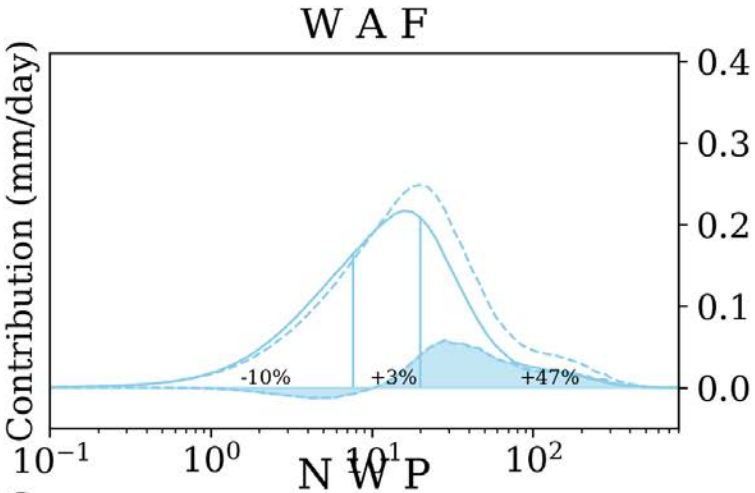
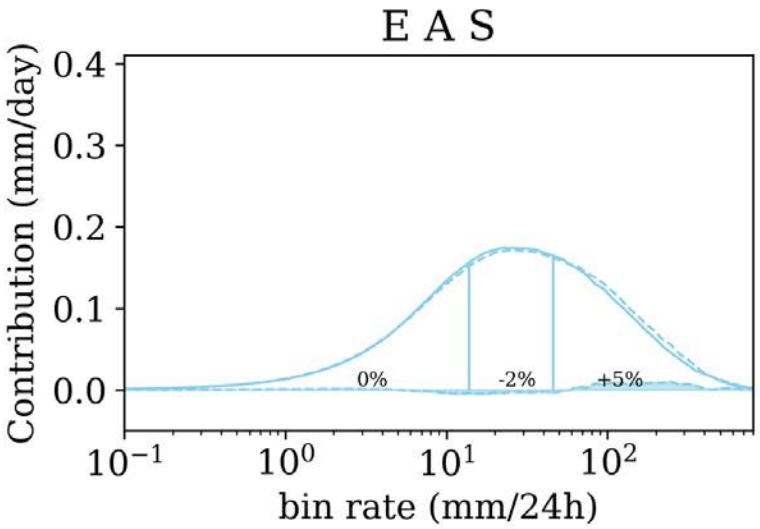
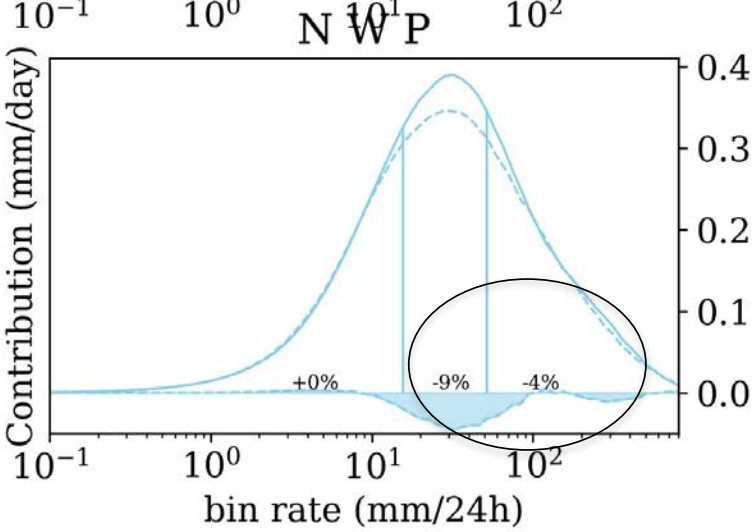






Not much changes in Eastern Asia at high resolution
Mostly decrease in medium intensities in North-West Pacific

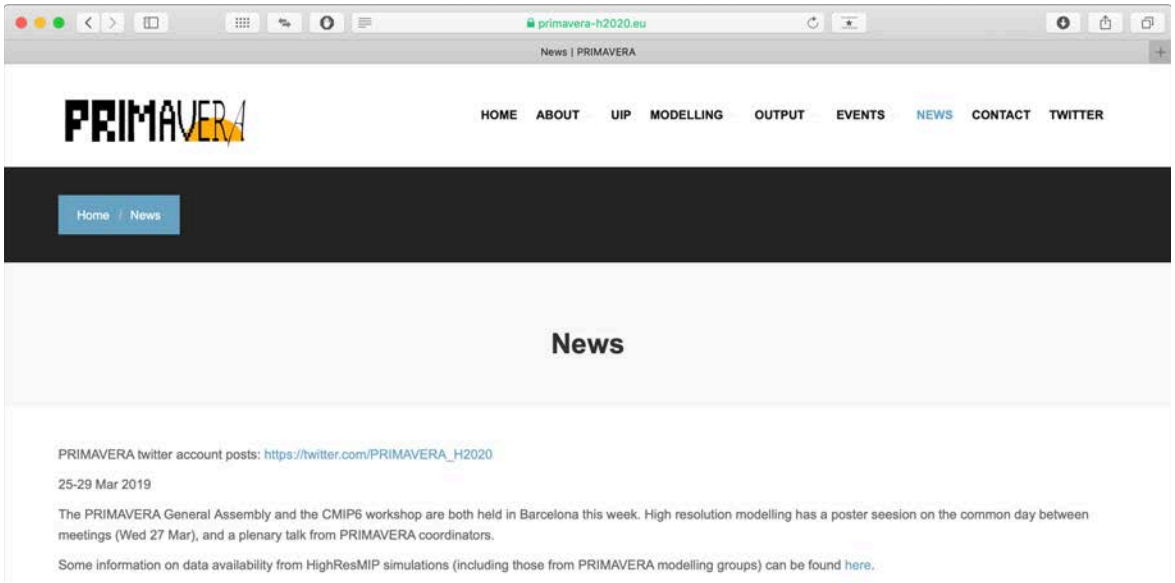
HighResMIP data availability

- Model output following HighResMIP data request
  - IPSL have already uploaded HighResMIP data to ESGF
    - https://esgf-node.llnl.gov/search/cmip6/
  - data from PRIMAVERA groups beginning to be copied to UK ESGF node at CEDA (Jon Seddon)
  - PRIMAVERA groups' models have
    - links at: https://www.primavera-h2020.eu/modelling/
    - searchable database of variables produced at:

    https://prima-dm.ceda.ac.uk/received_data/
  - several other groups known to have completed or are ongoing with HighResMIP simulations (GFDL, NICAM, FGOALS-f3-H, MPAS-A)

HighResMIP data availability (2)

- Derived or processed output
  - Big data volumes in CMIP6 encourages exploitation of derived or processed datasets produced **once** and shared often
    - to remove need to download every 6 hourly file to local disk from every model for every researcher
  - HighResMIP is producing a variety of derived outputs to share with the community
    - tropical cyclone storm tracks (using TRACK and TempestExtremes algorithms) will appear on CEDA data catalogue below
      - https://catalogue.ceda.ac.uk/uuid/18ea280ca1364c539468677926491e15
      - or search for HighResMIP under https://catalogue.ceda.ac.uk/
    - Climate extremes indices (calculated using CERFACS ICCLIM package)
      - available via Berkeley server (please ask Michael Wehner): http://portal.nersc.gov/archive/home/projects/cascade/www/ETCCDI/
    - Possibly AMOC-related diagnostics calculated following RAPID-MOCHA observations
      - using Christopher Roberts' code
    - Other suggestions? Should these be on ESGF instead or not?
- Questions for CMIP7
  - how to we make the data outputs manageable going forwards?
    - ever more variables, number of models, resolutions, etc etc



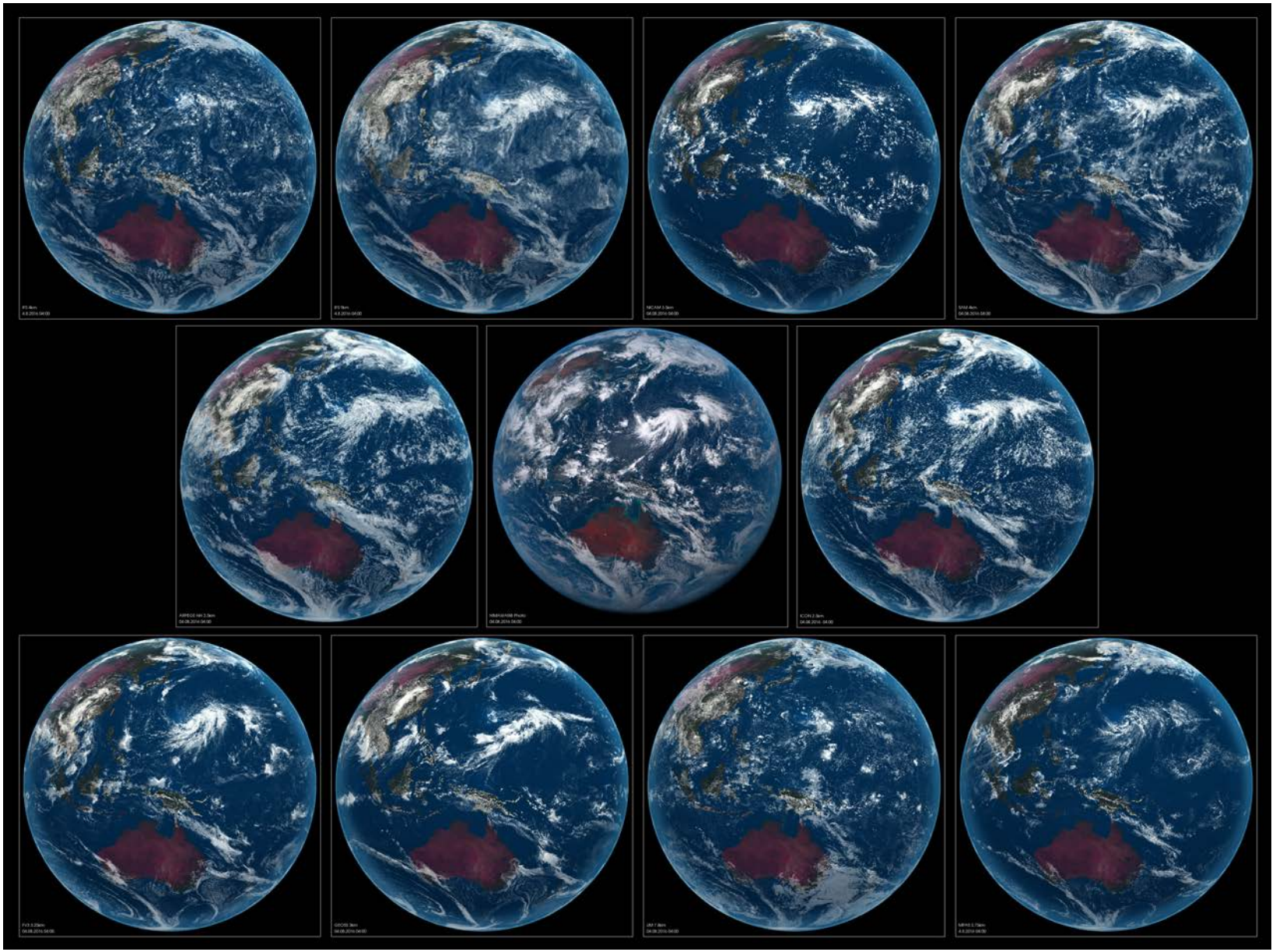
www.primavera-h2020.eu/news

collab.knmi.nl/highresmip/news

DYAMOND

Bjorn Stevens et al, J. Meteorological Society of Japan, special issue on DYAMOND:
The DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains

Snapshot of cloud condensate field from perspective of Himawari-8, 4 August 2016
9 models at sub-5km global resolution
Which one is from observations?



Questions

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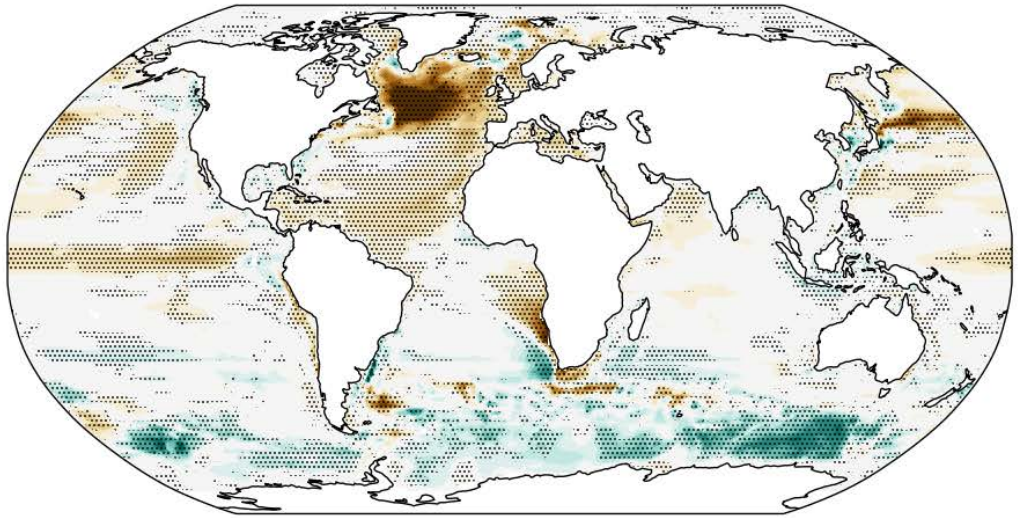
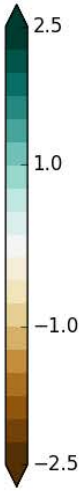
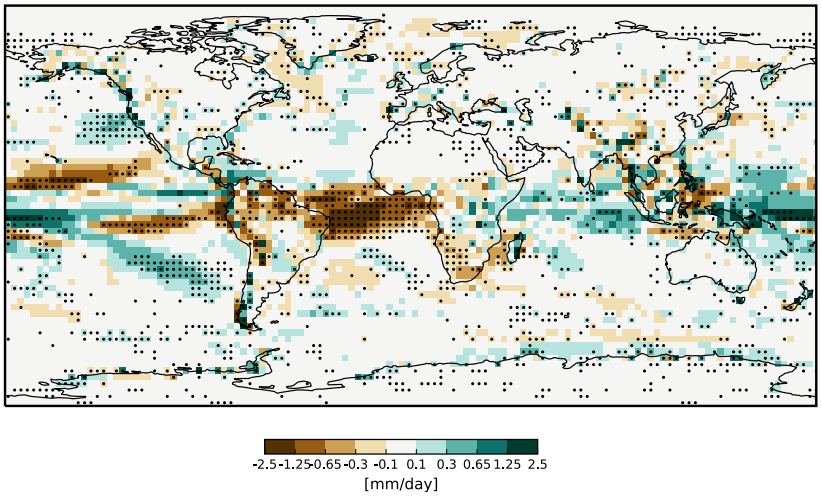
CMIP7 questions

- What does CMIP model data represent, and/or what do people think It represents?
  - is it meant to be the best models we can build?
  - or the best that everyone can afford?





RMS differences high – low models (as in Pier Luigi's talk)

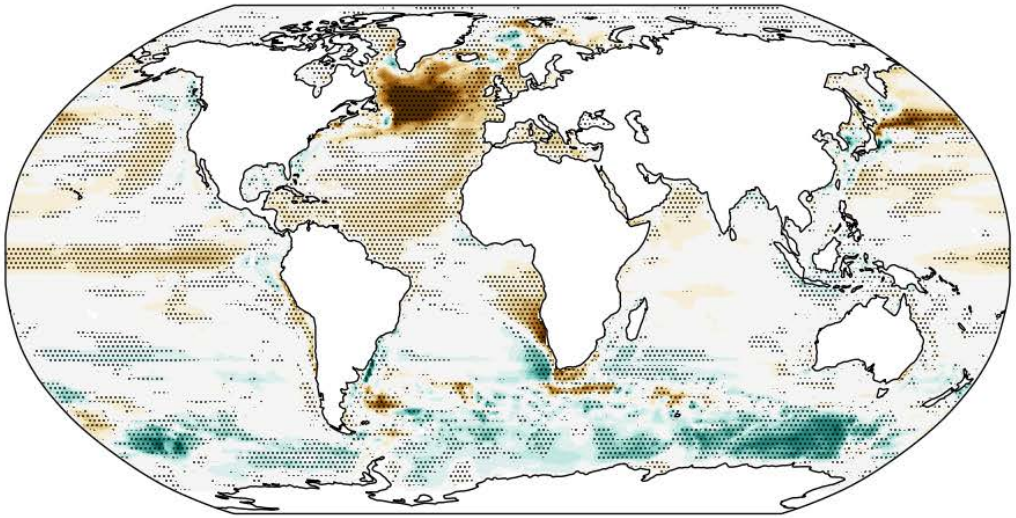


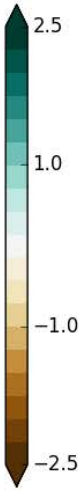
We know we can do better…

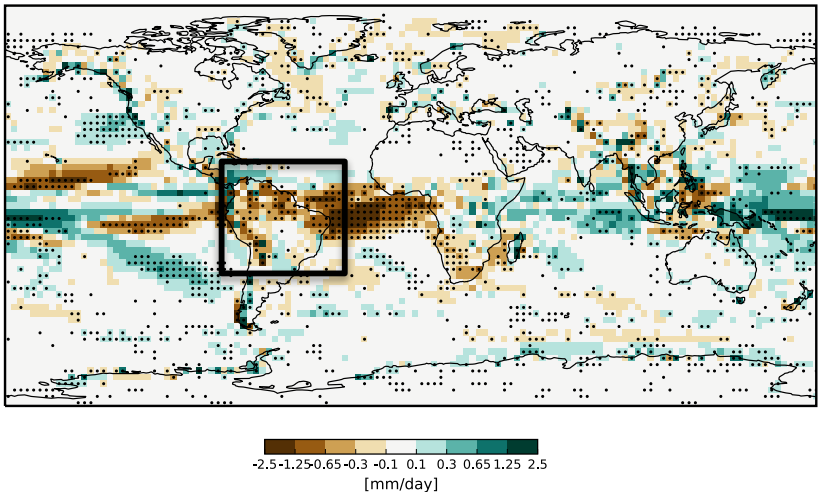
but it costs more

CMIP7 questions

- What does CMIP model data represent, and/or what do people think It represents?
  - is it meant to be the best models we can build?
  - but maybe it is better to have more models (and more complexity), and hence we compromise on the resolution
  - but…







If we use these global models to drive regional downscaling, are we confident that people who use the downscaled models are aware of the biases in the originating model, and their consequences?