Mesoscale air-sea interactions in Kuroshio Extension region during winter season simulated by a High-resolution Coupled GCM

Bo AN[1,2], Yongqiang YU[1,2], Pengfei LIN[1,2]
1 State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics, Chinese Academy of Sciences
2 University of Chinese Academy of Sciences

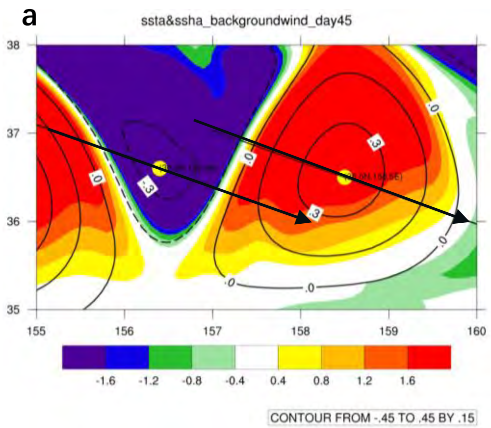
Mesoscale air-sea interaction mechanisms

- **vertical momentum mixing mechanism(Wallace et al., 1989)**
- **pressure adjustment mechanism (Lindzen and Nigam, 1987)**

- Data: a high resolution coupled GCM (Lin et al., 2019)
  oceanic component : LICOM2.0 (0.1°x0.1°)
  atmospheric component : CAM4 (0.23°x0.31°)

- Kuroshio Extension region (30°N-50°N，140°E-180°E)
  winter（ONDJFM）

- Method: 7-day temporal running mean
  LOESS(locally weighted regression) filter
  (Cleveland,1979)



"vertical momentum mixing mechanism", with significant vertical motions at the edge and vertical secondary circulations aloft.

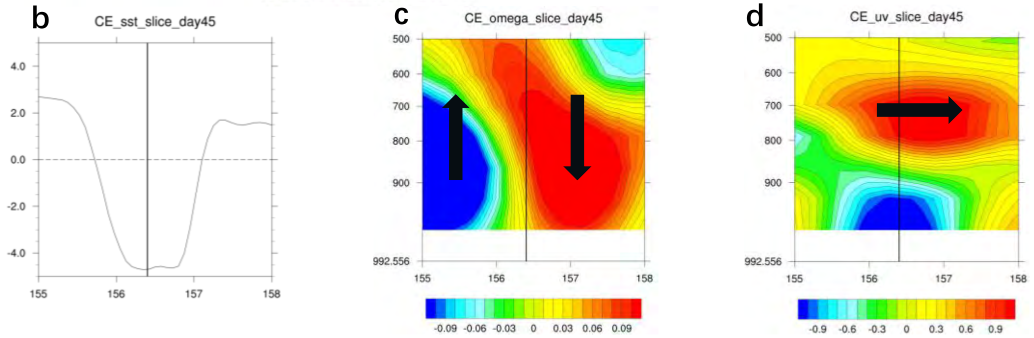


Fig 1

The high-pass-filtered SSTA corresponding with SSHA , with background wind direction indicated by the black line.(Fig 1a). The SSTA profiles across the eddy center along the black thick line for cold eddy..(Fig 1b) The vertical profiles of vertical and zonal wind anomaly along the same line for cold eddy. (Fig 1c d) www.bsc.es

PRIMAVERA

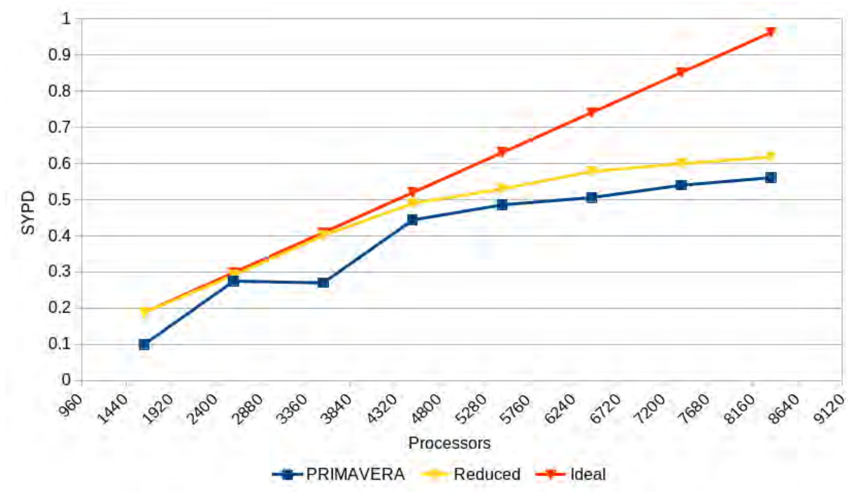
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

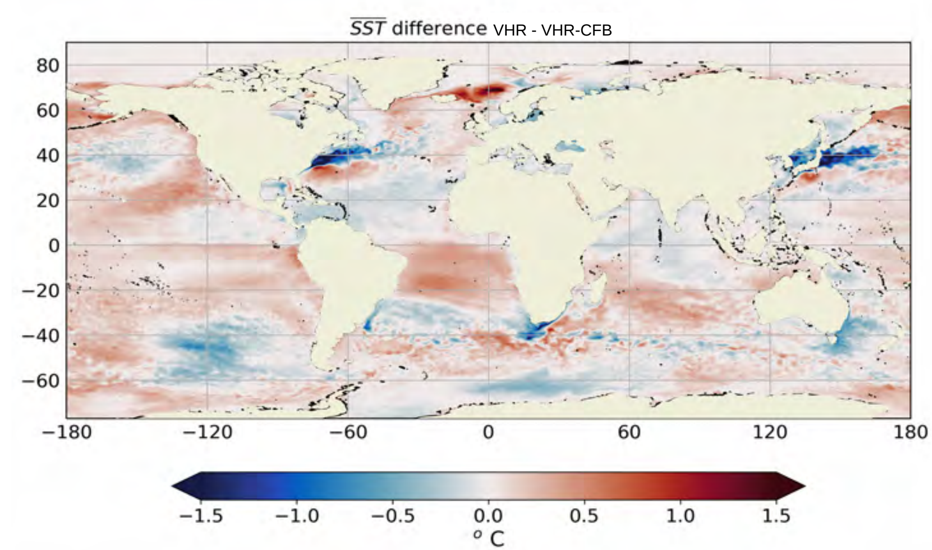
Running the EC-Earth model at ultra-high resolution: challenges and benefits

T. Arsouze (BSC), M. Castrillo (BSC), M. Acosta (BSC), L. Brodeau (OceanNext), L. Renault (LEGOS), P. Doblas-Reyes (BSC)

- EC-Earth v3.2 at "ultra-high resolution"
  - NEMO : ORCA12 (5-9km resolution),
  - IFS : T1279 (~15 km resolution),
  - OASIS : fields exchange every hour between ocean, atmosphere and surface-runoff scheme
- Simulation follows the HighResMIP protocole:
  - 50 years of spin-up with constant 1950 conditions
  - control + historical simulations
- Load balance and scalability tests of EC-Earth T1279-ORCA12 configuration on MareNostrum4

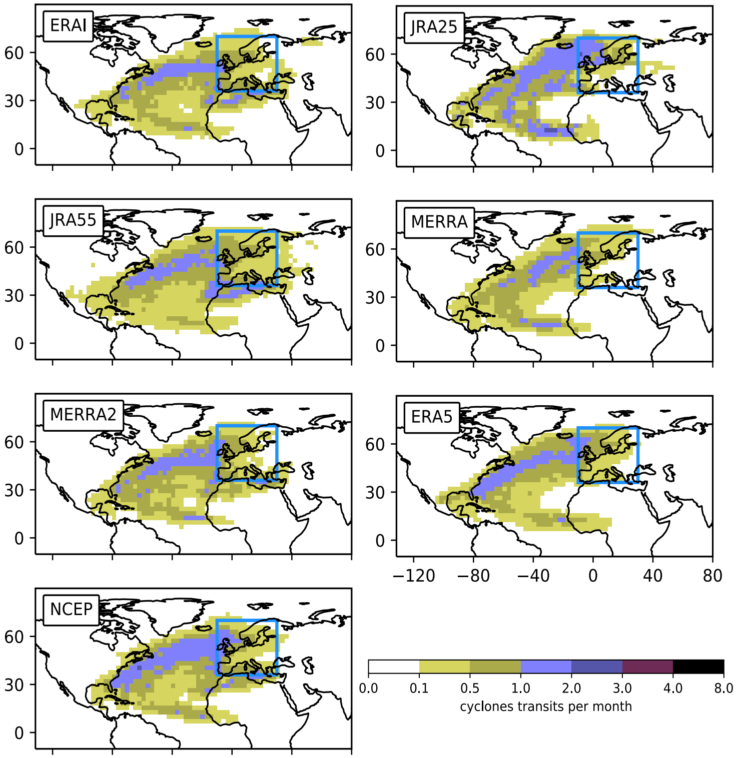


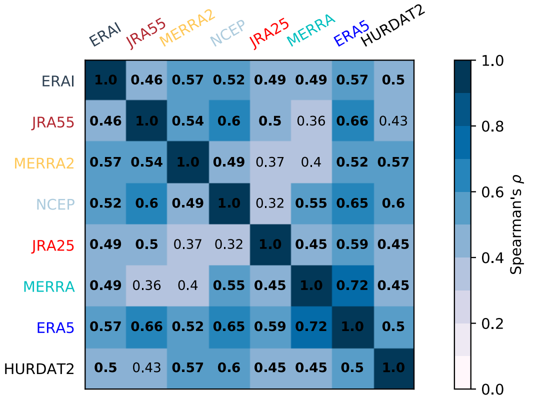
- Scientific objectives:
  - Develop, prepare and evaluate a new generation of global high-resolution climate models
  - Evaluate the role of the mechanical interactions between oceanic surface currents and atmospheric winds ("current-feedback")

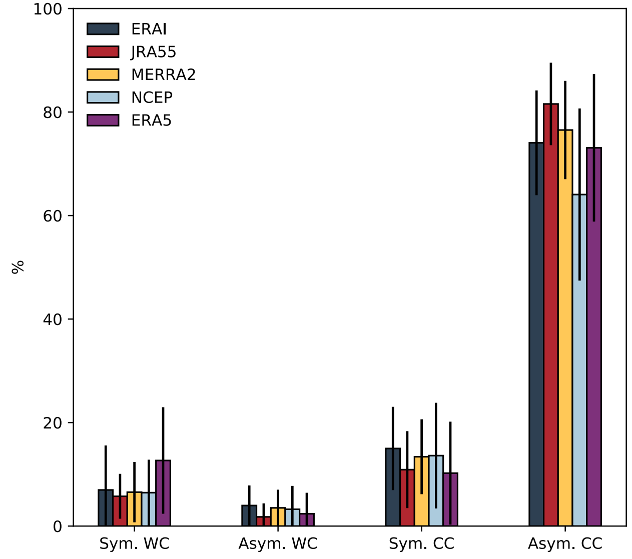


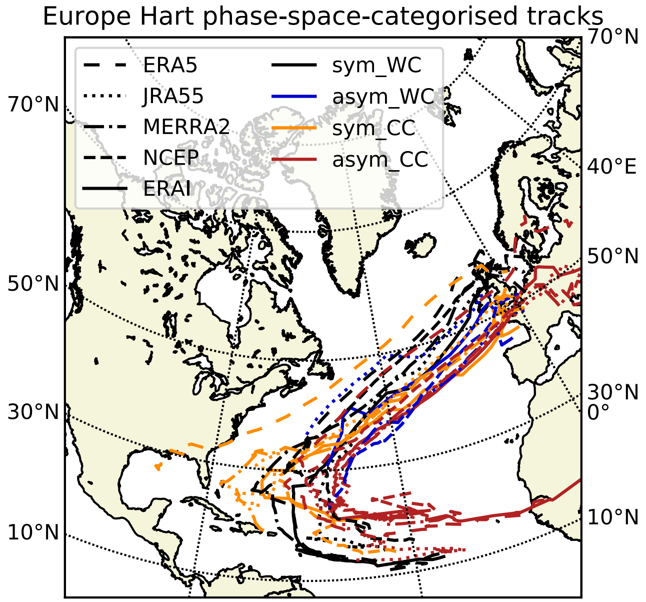
North Atlantic post-tropical cyclones

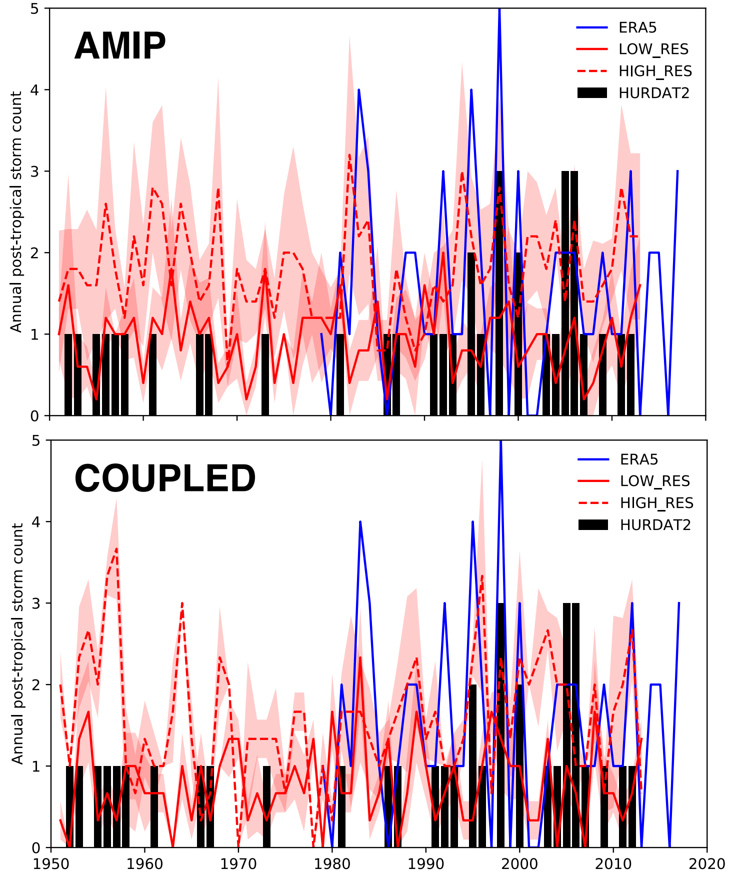
Alex Baker*, Kevin Hodges, Rein Haarsma, Reinhard Schiemann, and Pier Luigi Vidale











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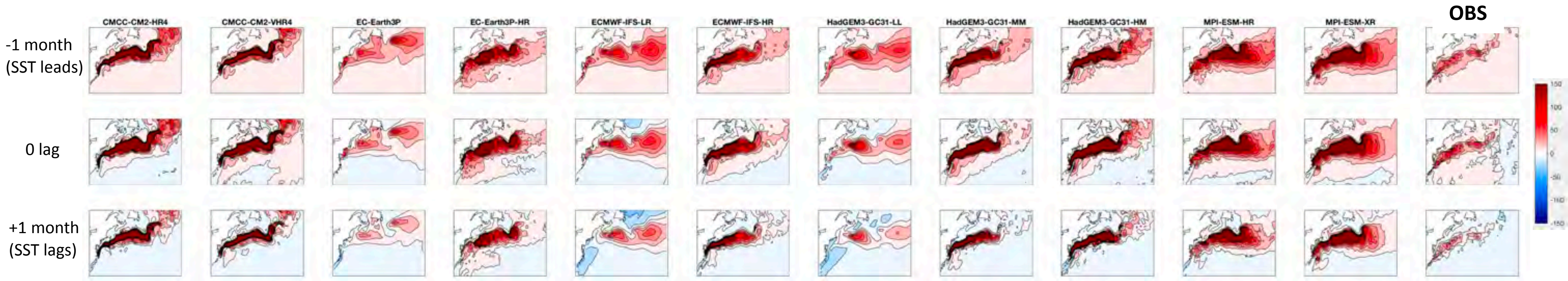
University of Reading

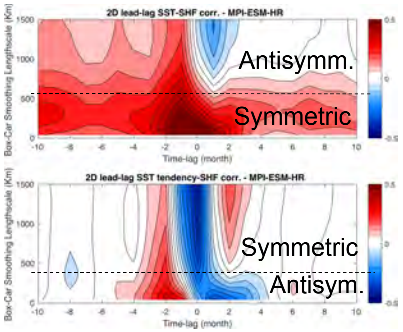
National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

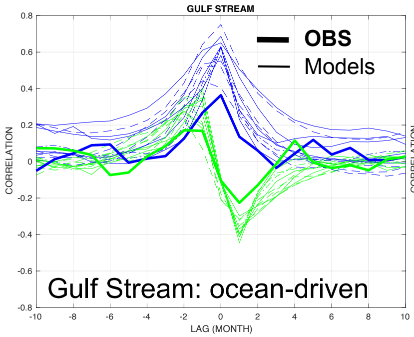
Air-Sea interactions over the Gulf Stream in an ensemble of HighResMIP present climate simulations

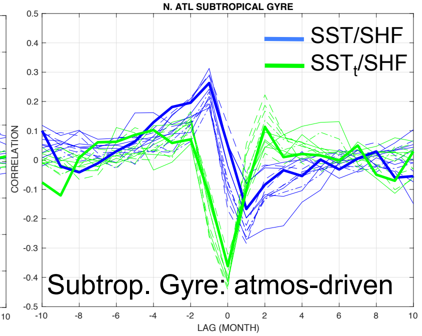
***A. Bellucci**, P. Athanasiadis, E. Scoccimarro, P. Ruggieri, G. Fedele, R. Haarsma, J. Garcia-Serrano, I. de Vries, and S. Gualdi*

- Role of model resolution in the representation of air-sea interactions over the Gulf Stream
- 11-model HighResMIP ensemble, where both laminar and eddy-permitting ocean GCMs are coupled with atmospheres at different resolutions.
- Use lead-lag SST-Turbulent Heat Flux covariance patterns to reveal whether SST variability is driven by atmospheric weather or oceanic intrinsic variability
- WBC-Open Ocean regime transition is robustly captured across HighResMIP hierarchy
- Phase relationship between SST and Heat Fluxes weakly affected by resolution
- High resolution amplifies covariance strength but improves spatial structure









SESSION 4 - P04

Influence of large-scale circulation on European surface wind projections

Paula Gonzalez, David Brayshaw, Giuseppe Zappa (Clim Dyn, in review)

Context:

- Growing importance of wind power
- Limited understanding of inter-model uncertainty in wind projections over C21
- ➔ identify component associated with large-scale winter-time circulation change

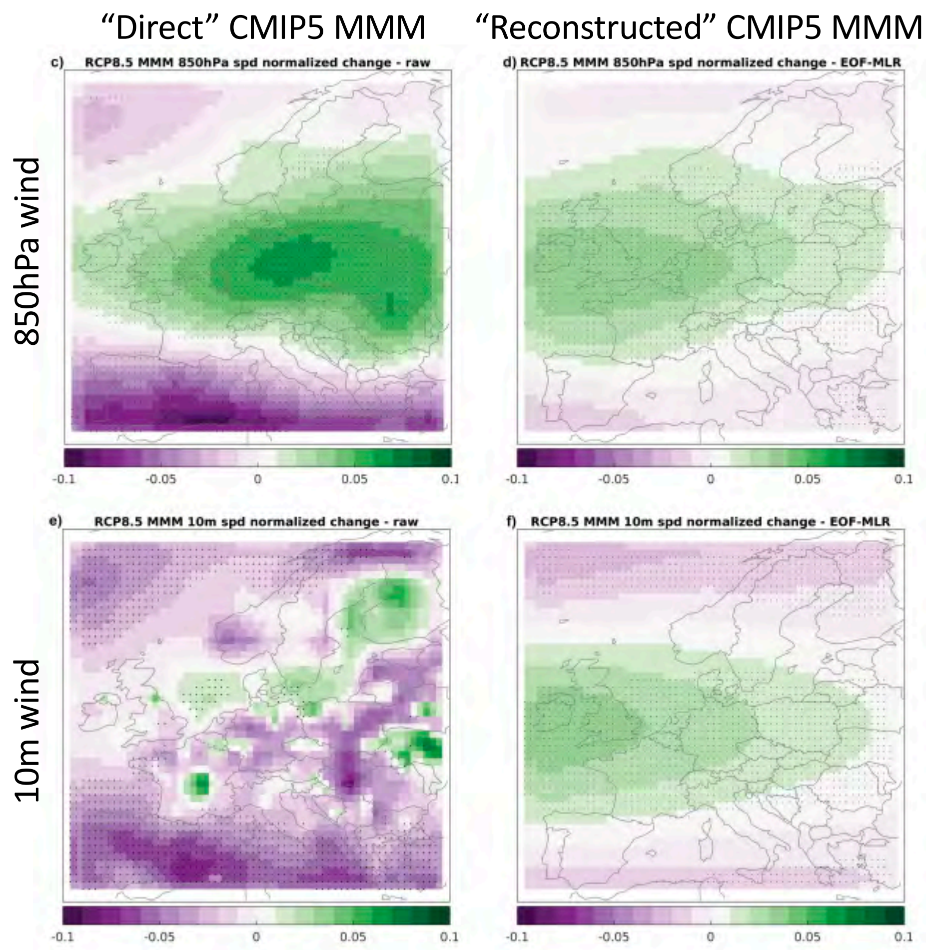
Method:

- Project time-mean RCP8.5 850 hPa circulation onto seasonal EOFs 1&2
- Assume historic link EOFs → surface wind (MLR)
- Reconstruct future 10m wind projection using EOFs+MLR
- Compare against direct C21 10m wind projection

Conclusions:

- 10m wind speed change in CMIP5 GCMs *not* well explained by large scale circulation response
    - Very uncertain large scale circulation response
    - Robust negative "residual" likely associated with boundary layer effects

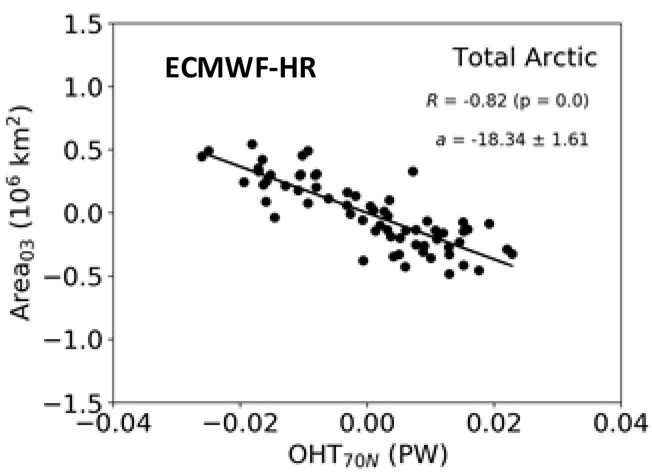
➔ Caution needed in interpreting wind-speed projections

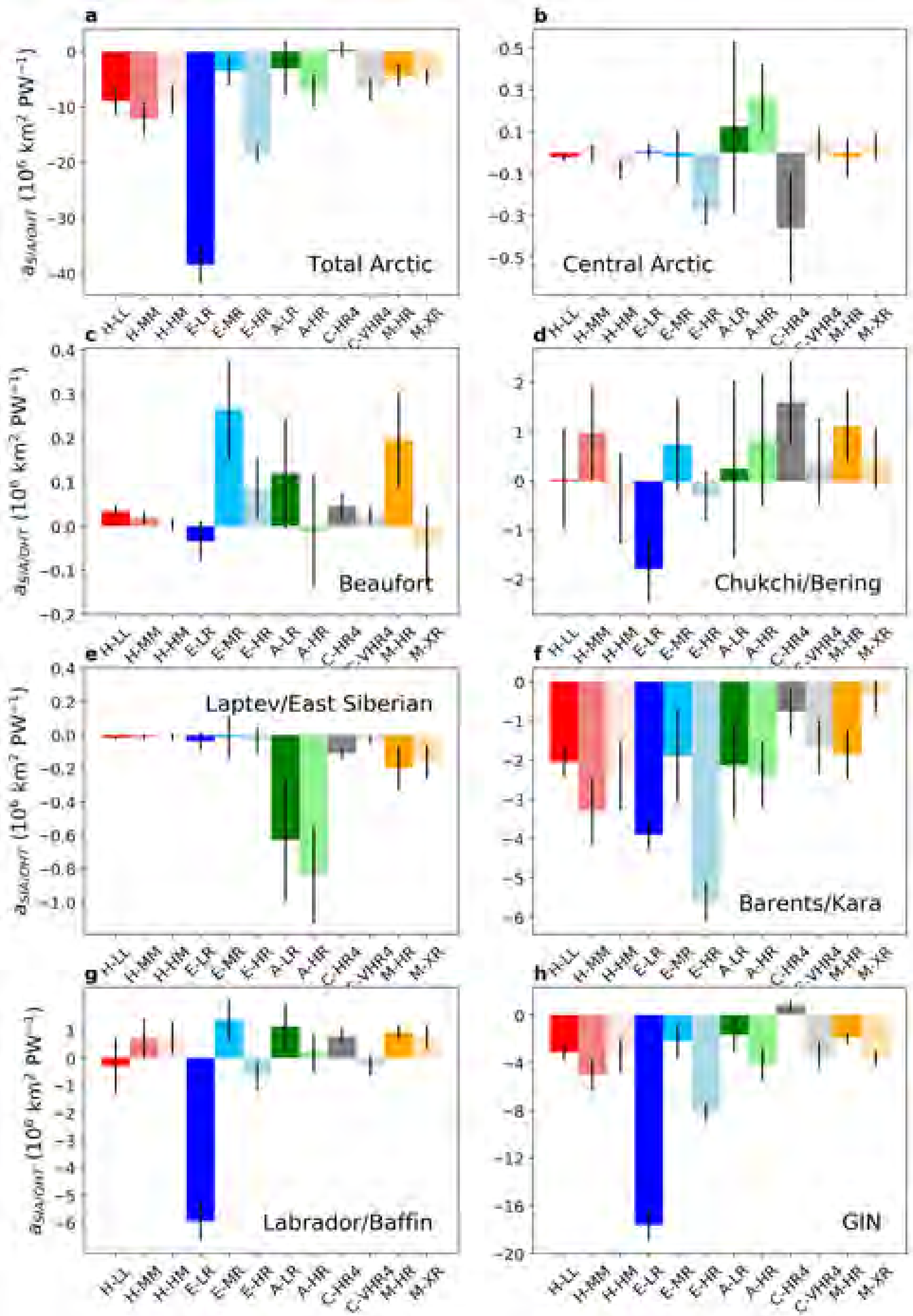


This project has received funding from the European Union's Horizon 2020 Research & Innovation Programme under grant agreement no. 641727.

Impact of model resolution on Arctic sea ice and North Atlantic Ocean heat transport

David Docquier, J.P. Grist, M.J. Roberts, C.D. Roberts, T. Semmler, L. Ponsoni, F. Massonnet, D. Sidorenko, D. Sein, D. Iovino, A. Bellucci, T. Fichefet





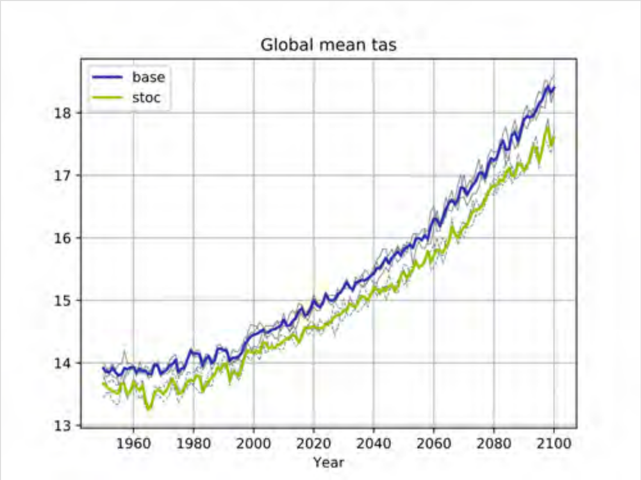
Impact of stochastic physics on climate simulations with EC-Earth: looking at the atmosphere

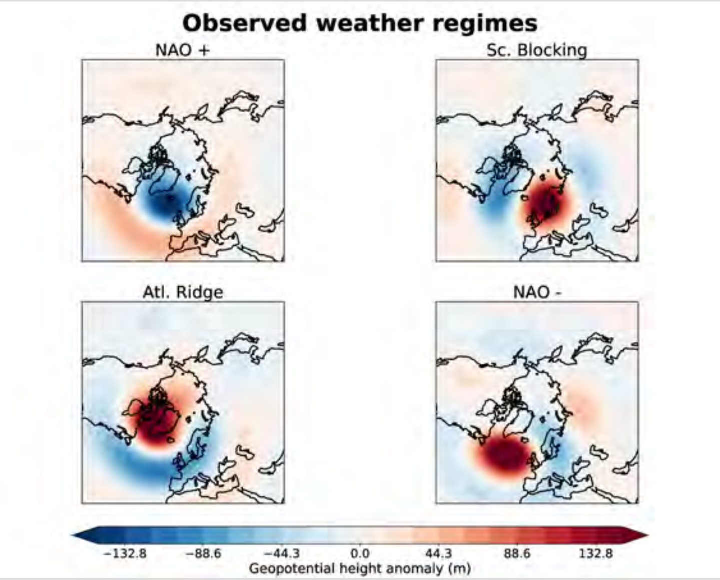
Federico Fabiano, Virna Meccia, Susanna Corti

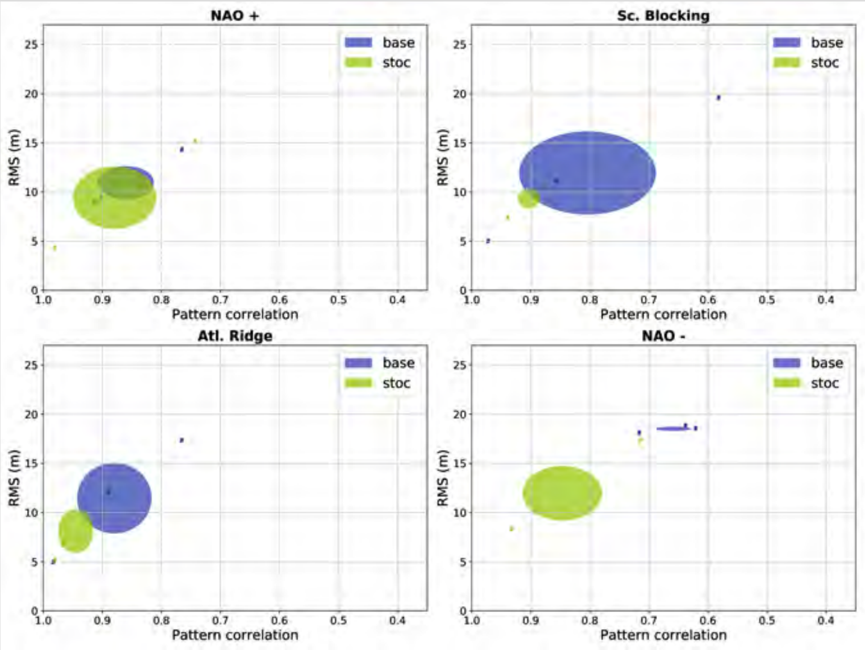
Inclusion of stochastic physics (SP) schemes in climate models have been shown to significantly shift the model mean state. Here we analyze two set of EC-Earth coupled climate simulations with and without SP.

We study the impact of SP on:

- the model mean state: radiation budget, meridional heat flux and zonal mean temperature;
- the representation of Weather Regimes in the North Atlantic.



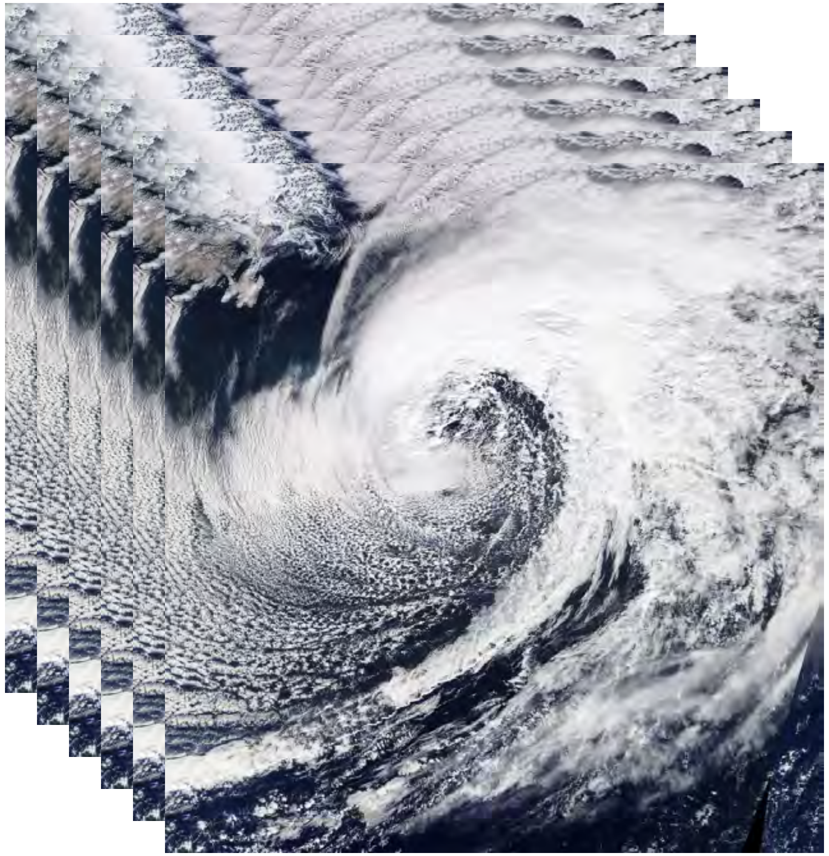


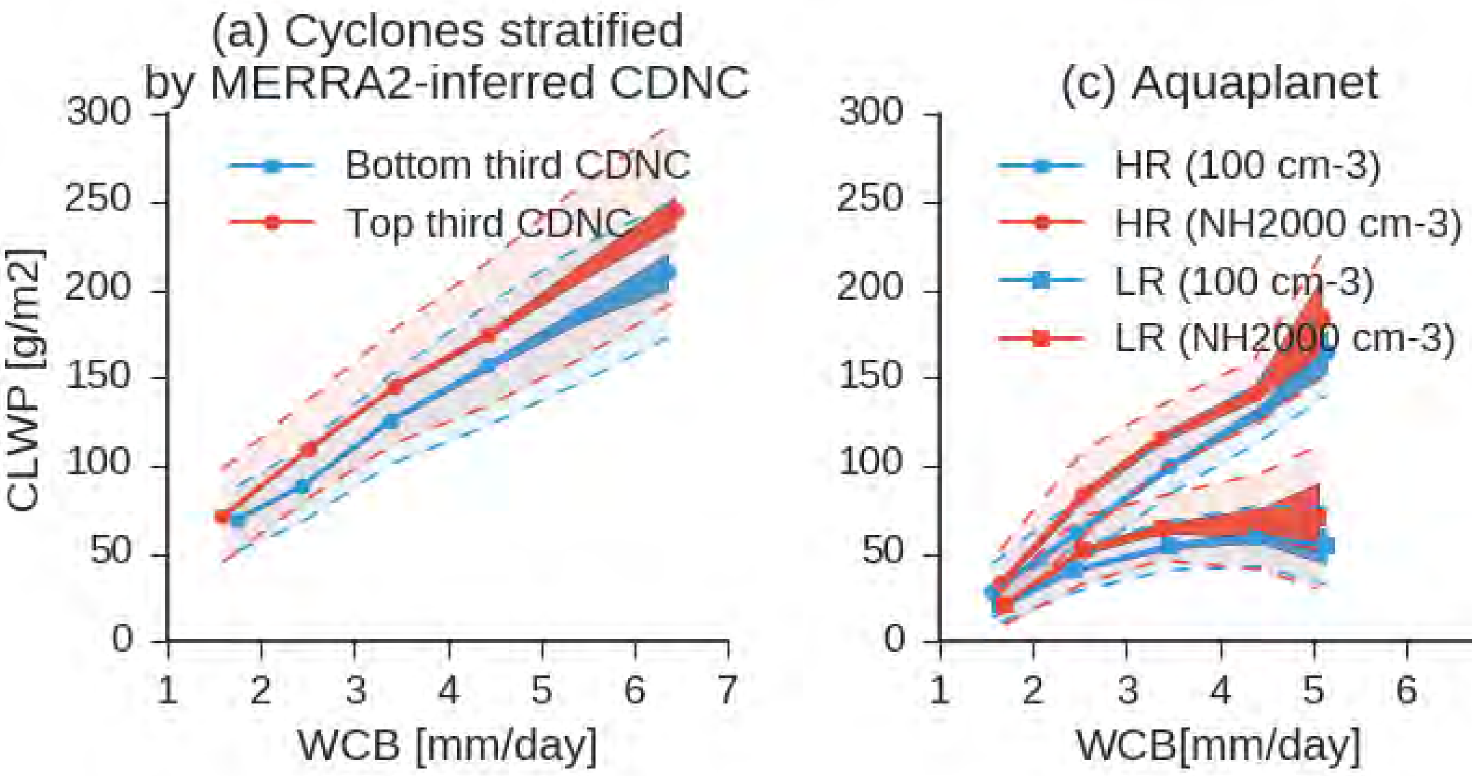


Session 4
Poster P07

ISAC
Consiglio Nazionale delle Ricerche
Istituto di Scienze dell'Atmosfera e del Clima

Aerosol midlatitude cyclone indirect effects in observations and high-resolution simulations. [4 P08 Field Paul]





- Composited Mid-Latitude Cyclones
  - Observations
  - ~7km convection permitting global model
  - ~100km parametrized convection global model

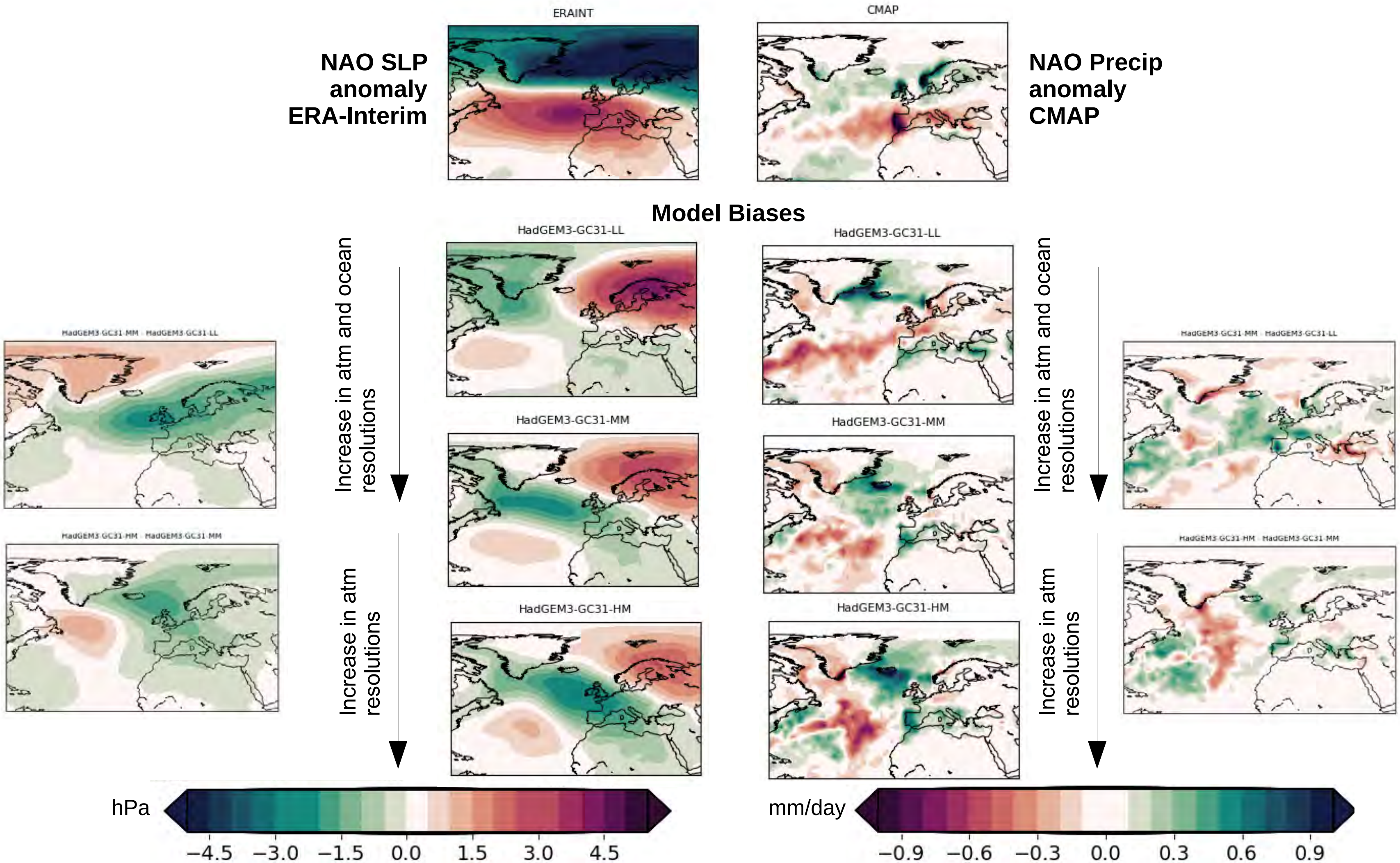
- For constant rainrate, higher droplet number leads to higher liquid water path in obs and models

- Low resolution parametrized convection model less realistic behaviour than high resolution convection permitting model.

Impact of changes in atmospheric and ocean model resolution on modes of variability in historical coupled model simulations

Ramón Fuentes-Franco, Torben Koenigk, Klaus Zimmermann

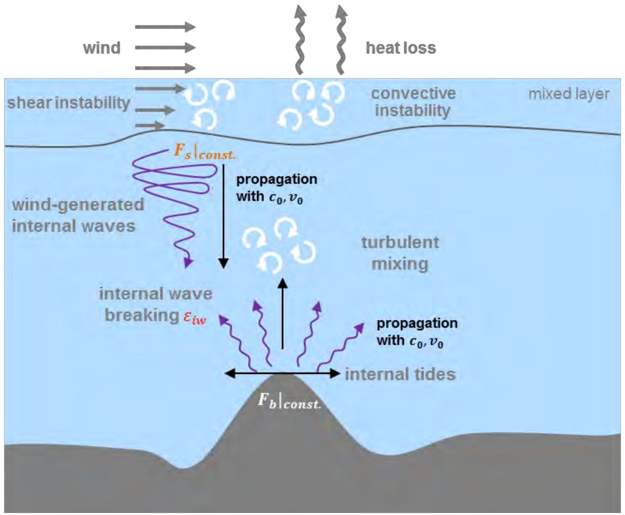
In an inter-model comparison across different atmospheric and ocean model resolutions, we analyse differences on the representation of spatial patterns, intensities of El Nino Southern Oscillation (ENSO), the Atlantic Multidecadal Oscillation (AMO), the Pacific Decadal Oscillation (PDO), the North Atlantic Oscillation (NAO) and the Pacific North America pattern (PNA) compared with observations and reanalysis

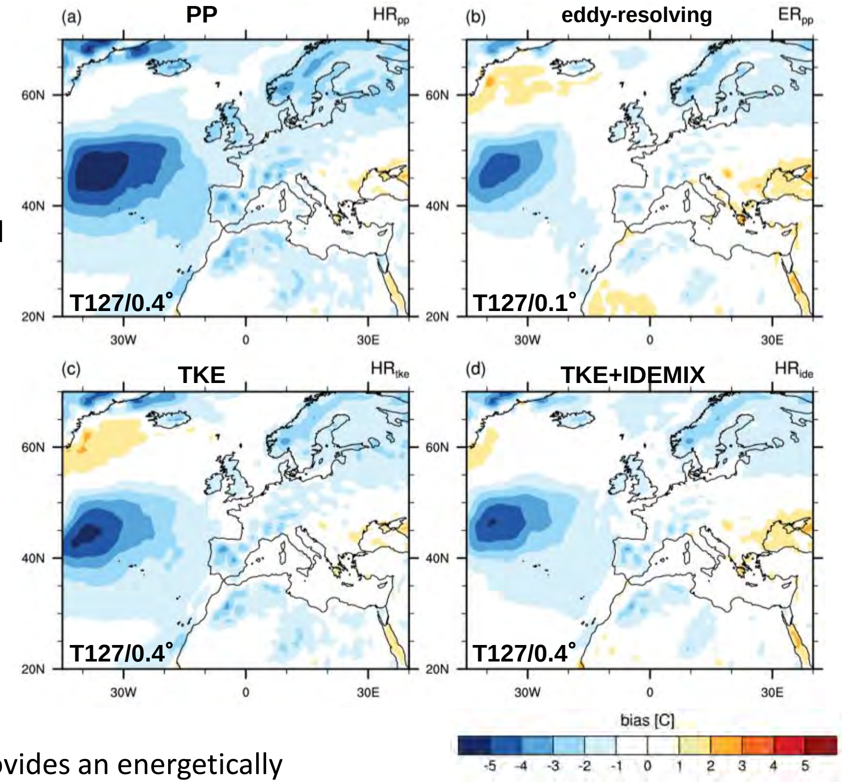


Towards an energetically consistent vertical ocean mixing scheme in MPI-ESM1.2

O. Gutjahr[1], J. H. Jungclaus[1], N. Brüggemann[2,1], H. Haak[1]
[1]Max Planck Institute for Meteorology, Hamburg; [2]University of Hamburg, Institut für Meereskunde

- internal wave breaking not resolved in ocean models
- a simple constant background diffusivity below mixed layer creates artificial energy
- we replace the constant background diffusivity of the TKE scheme with the Internal Wave Dissipation, Energy and Mixing (**IDEMIX**) scheme





Conclusions:

- IDEMIX provides an energetically consistent ocean vertical mixing scheme
- IDEMIX reduces cold bias over North Atlantic / Europe as with an eddy-resolving ocean

Poster session 4 – P10

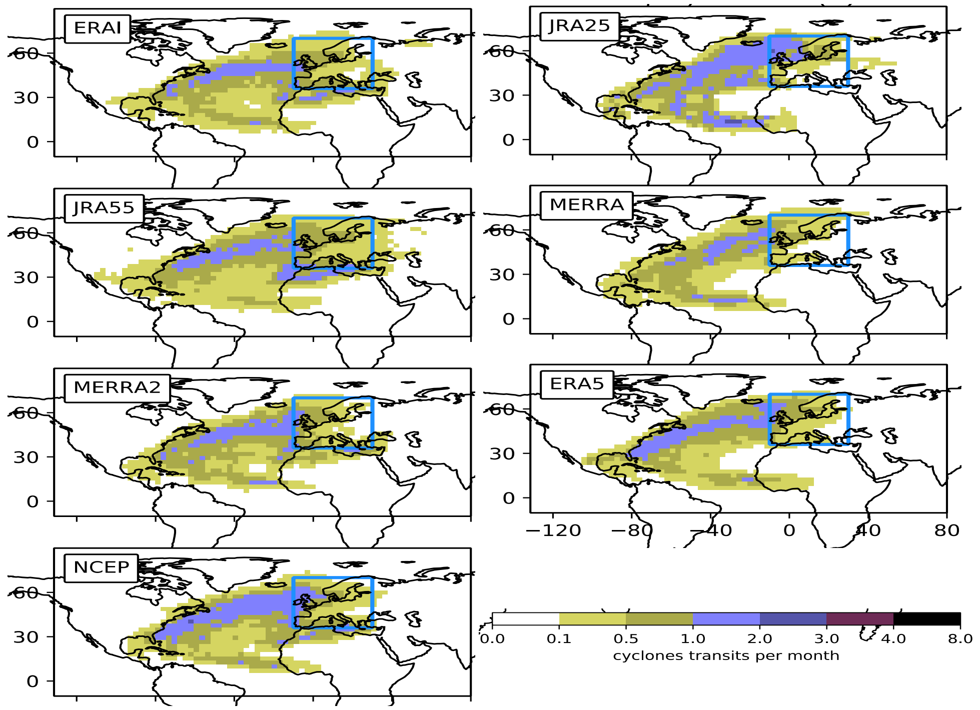
Co-funded by the European Union
PRIMAVERA

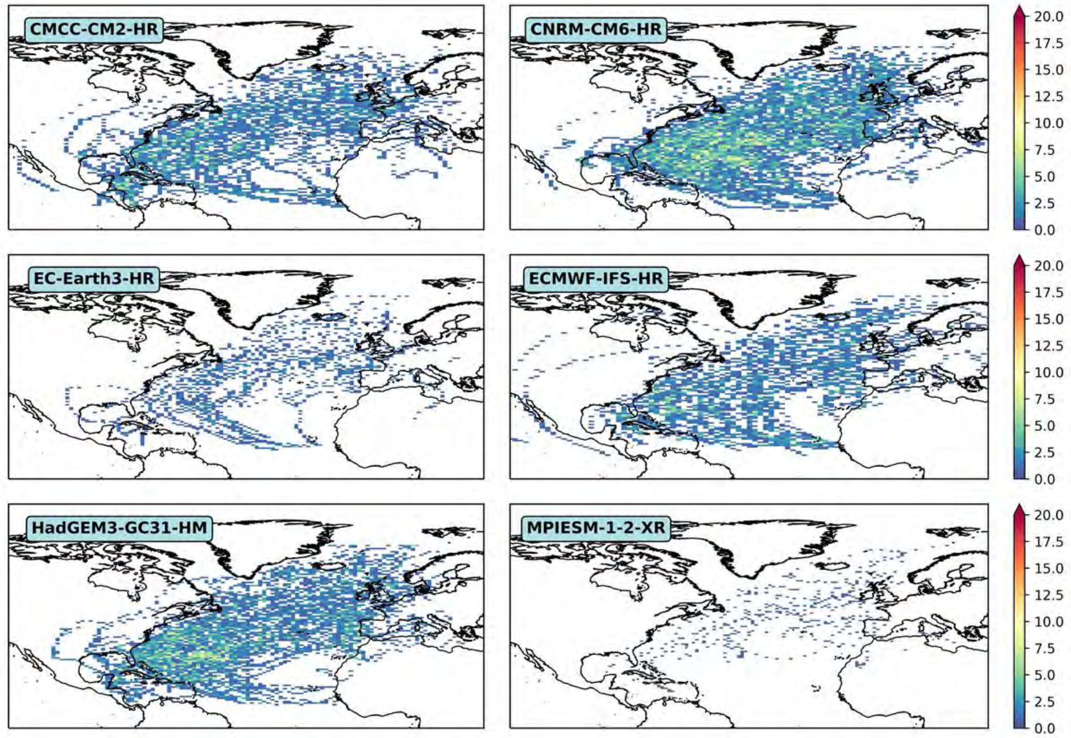
Extra-tropical transition of Atlantic hurricanes in Primavera HighResMIP

Rein Haarsma[1], Dimitris Kapetanakis[1], Alex Baker[2]
[1]KNMI, [2]Univ. Reading

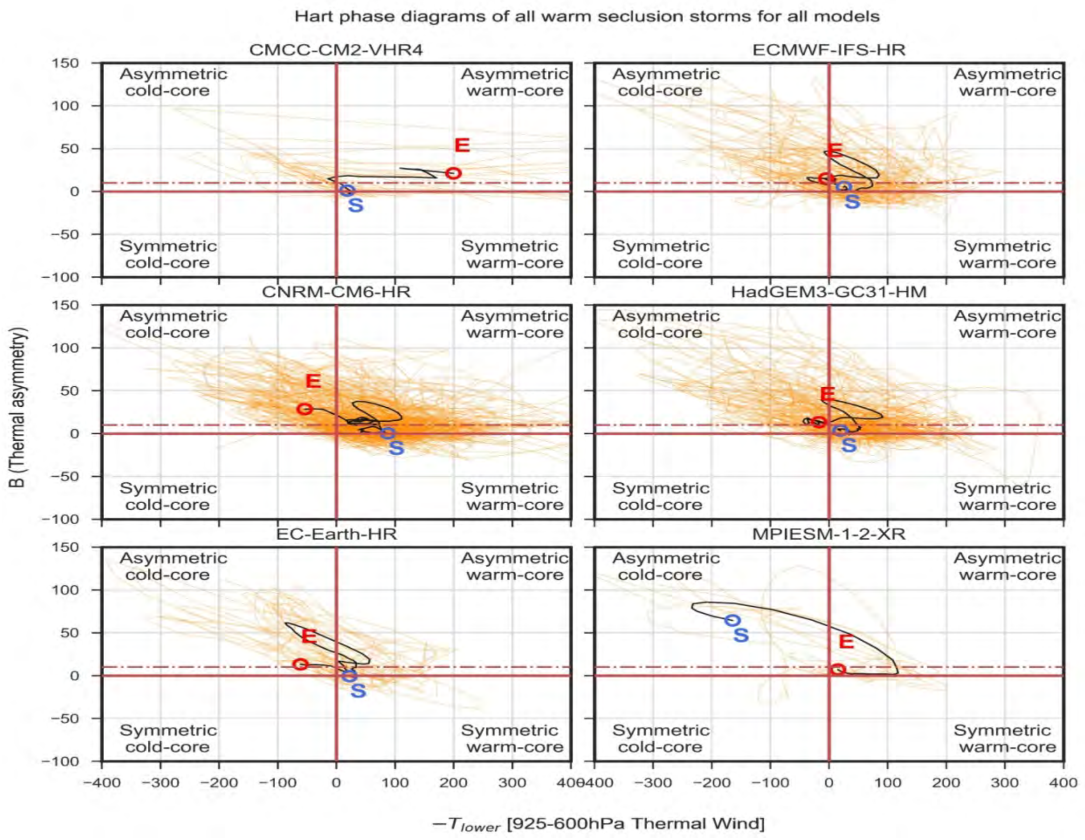
The extra-tropical transition of North Atlantic hurricanes in HighResMIP Stream1 PRIMAVERA simulations has been analyzed. Only the ones that reach Europe are considered. Most PRIMAVERA models display reasonably agreement with reanalyses. About 50% of the storms that reach Europe are warm seclusion storms. These are also the strongest storms.

Track density





Hart diagrams



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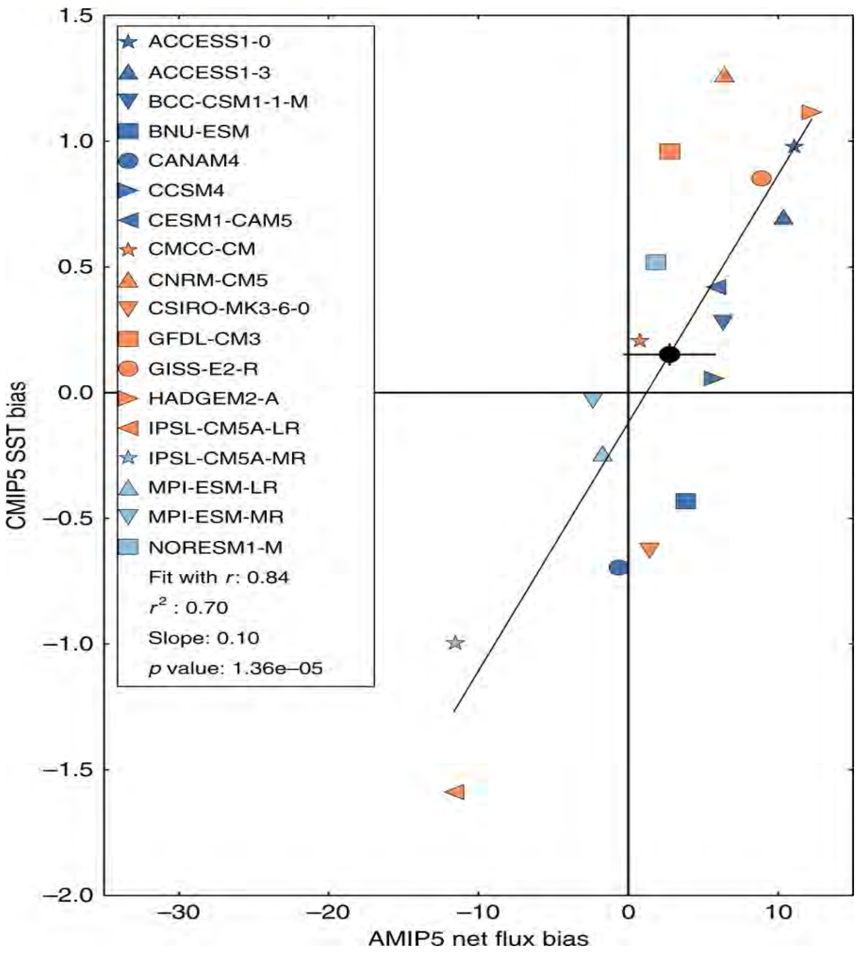
PRIMAVERA

Southern Ocean climate model biases traced to atmospheric model cloud errors

(Hyder, **Hewitt** *et al.*, *Nature Comms*, 2018)

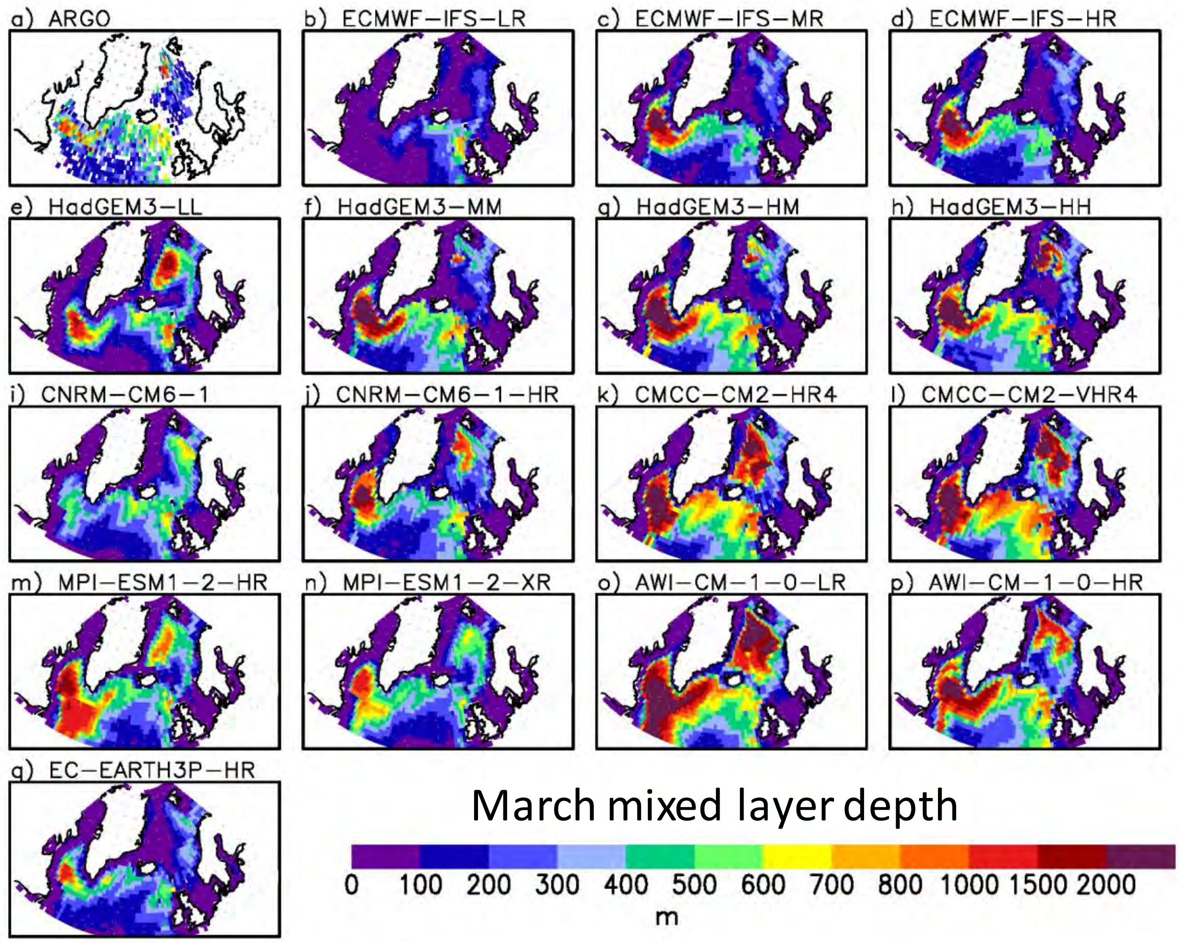


- IPCC coupled climate models generally have warm Southern Ocean SST biases.
- Correlations between historical period coupled model SST biases and atmosphere-only net and short-wave surface flux errors are 0.84 (fig) and 0.73, respectively.
- Most models with good SST biases achieve this by error cancellation between heat flux components.
- Targeted developments to our CMIP6 model atmospheric configuration have reduced the 40-60ºS net flux bias by ~65% and coupled SST biases by ~75%.

Deep water formation in the North Atlantic Ocean in high resolution global coupled climate models

T. Koenigk and R. Fuentes Franco

- HighResMIP-simulations from 7 coupled models
- Index for deep convection in the North Atlantic
- Impact of surface heat fluxes on the convection



Conclusion

Resolution affects the surface heat flux and the deep water formation in the North Atlantic.

→ **Poster P14**

HORIZON 2020
PRIMAVERA has received funding from the European Union's Horizon 2020 Programme for Research and Innovation, under Grant Agreement no 641727.

PRIMAVERA

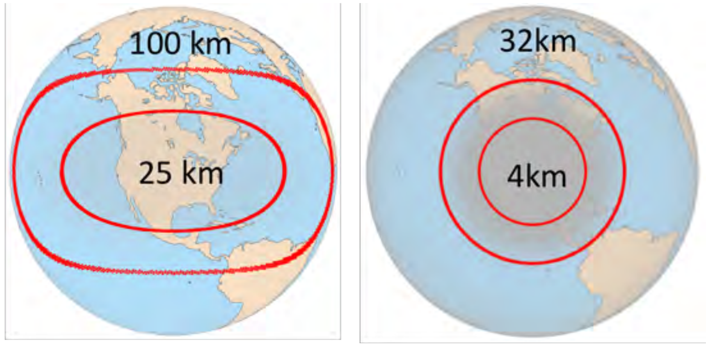
Analysis of Mesoscale Convective Systems in MPAS-CAM5 High Resolution and Convection Permitting Simulations

L. Ruby Leung, Koichi Sakaguchi, Bryce Harrop, Zhe Feng, Fengfei Song, and Robert Houze

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

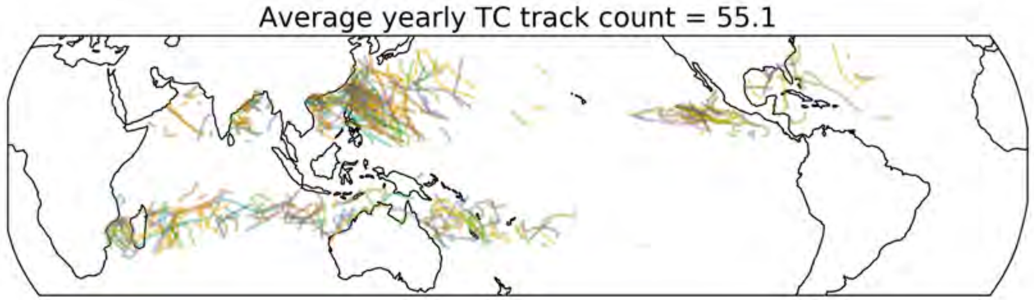
- Model for Prediction Across Scales (MPAS) is a global, non-hydrostatic dynamical core on an unstructured Voronoi mesh (Skamarock et al. 2012), coupled with the physics package of Community Atmosphere Model (CAM)
- MPAS can be flexibly configured for quasi-uniform and variable resolutions
- Both uniform- and variable-resolution configurations are used to study extreme events and to contribute to model comparison projects, such as CMIP6 HighResMIP

Uniform resolution (UR)

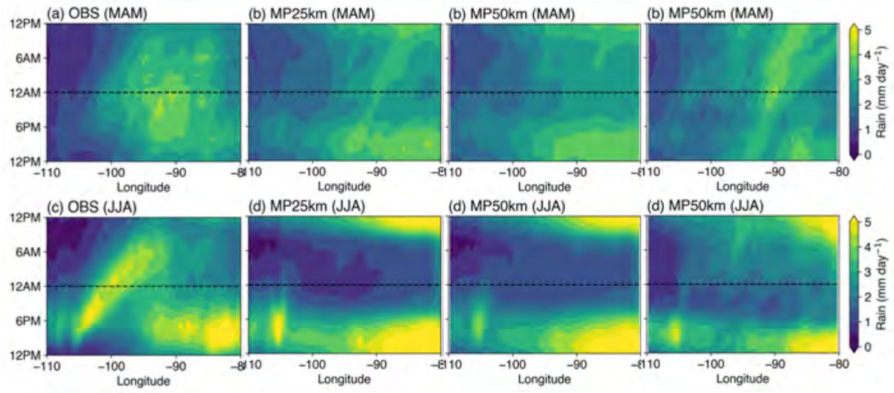


Variable resolution (VR)

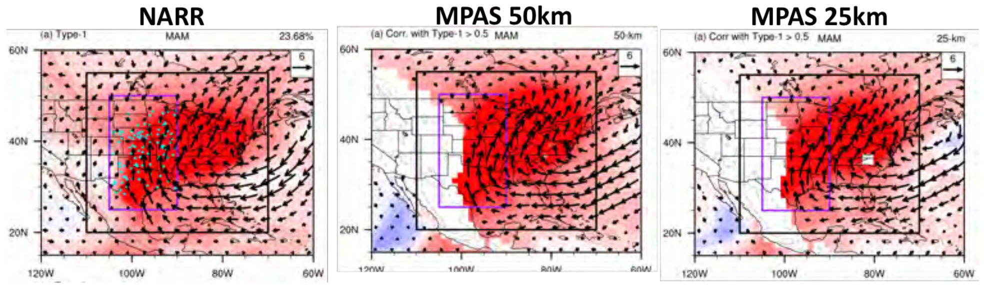
Tropical cyclone tracks in HighResMIP 30 km simulation



MPAS-CAM simulations at 50km and 25km Precipitation in the Central U.S.



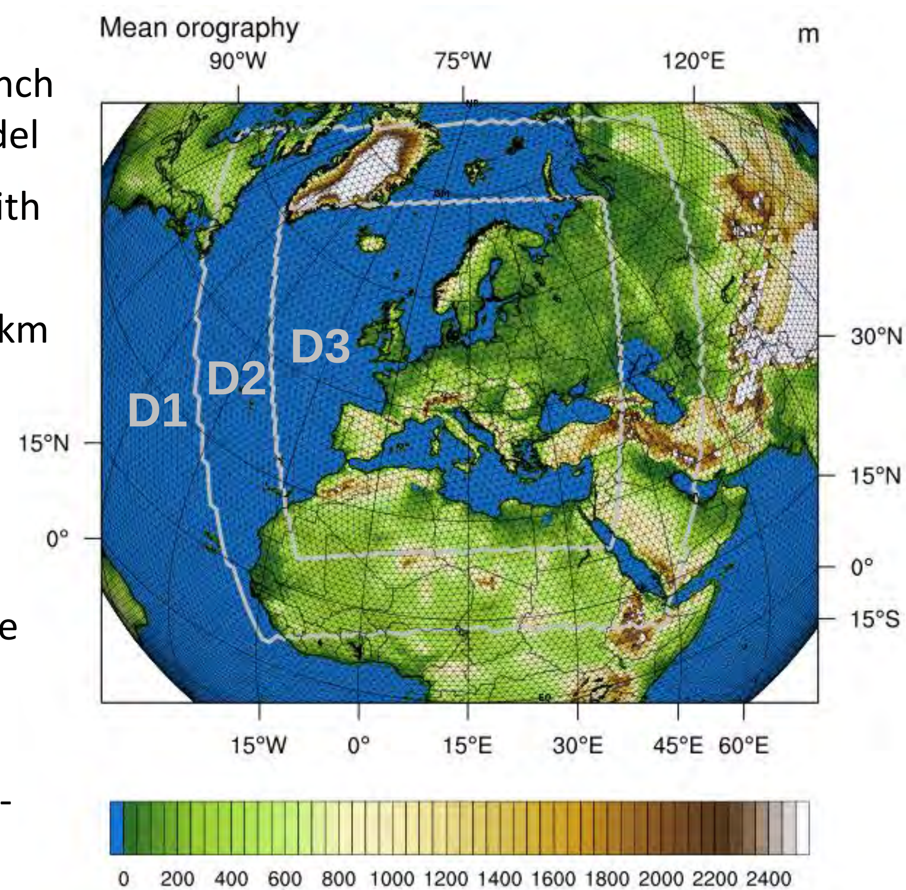
925 hPa wind and specific humidity anomalies of MCSs



Climate modeling with a multi-grid approach

Vera Maurer, Christian Steger, Barbara Früh, Jennifer Brauch

- The multi-grid approach (very similar to 2-way nesting) was implemented into the climate branch of the ICOsahedral Non-hydrostatic (ICON) model
- Aim: climate projections with ICON-ESM and with individual higher-resolved domains
- <u>**Results**</u> for a simulation with globally about 80 km and two subdomains over Europe with about 40 km and 20 km
- Benefit of higher resolution mainly for precipitation
- Tuning required for higher resolution, otherwise the feedback to the parent (global) domain can deteriorate the whole simulation
- Coupling with the global ICON-O (ocean component) can be accomplished „easily“

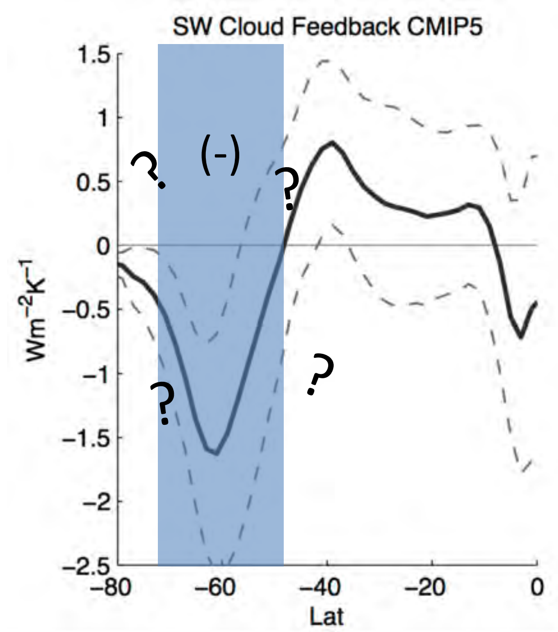


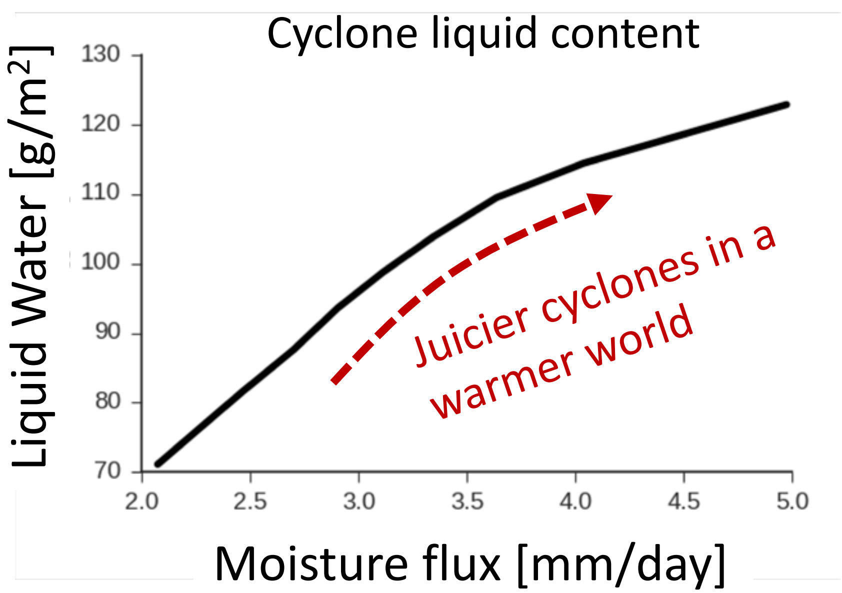
Cloud feedbacks in extratropical cyclones

DT McCoy, PR Field, and coauthors

UNIVERSITY OF LEEDS

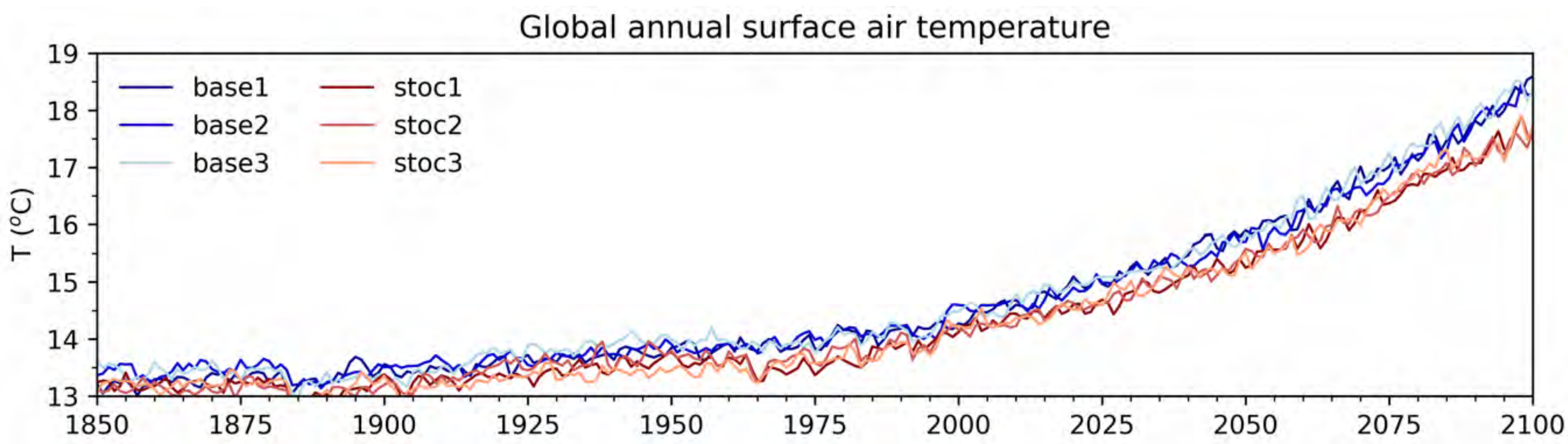
- CMIP3/5 GCMs all had a strong negative shortwave cloud feedback in the extratropics.
- This is supported by observed long-term trends in cloud properties in the Southern Ocean.
- We show that this cyclone behavior in GCMs and observations can be explained by changes in moisture flux.





- All models increase cyclone liquid water path (and brightness) as moisture flux increases.
- Not strongly dependent on model resolution.
- Similar large-scale dynamical controls on moisture flux in all models.

Impact of stochastic physics on climate simulations with EC-Earth: looking at the ocean



Virna Meccia, Federico Fabiano and Susanna Corti

Institute of Atmospheric Sciences and Climate, Italy.

Session 4

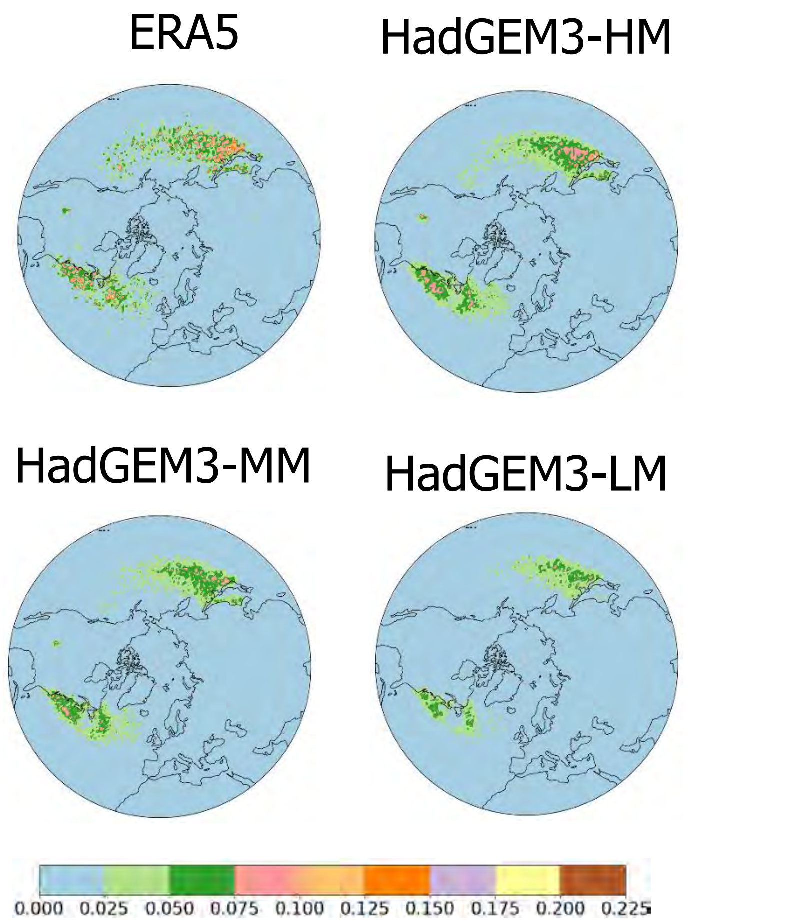
Poster P18

Bomb Cyclones in PRIMAVERA Simulations

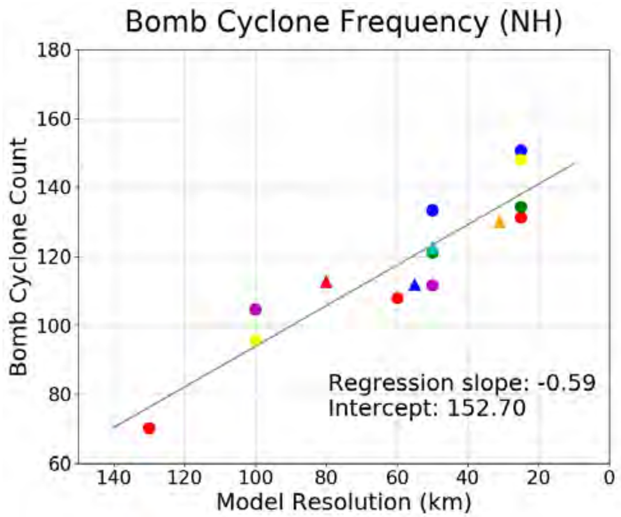
4-P19

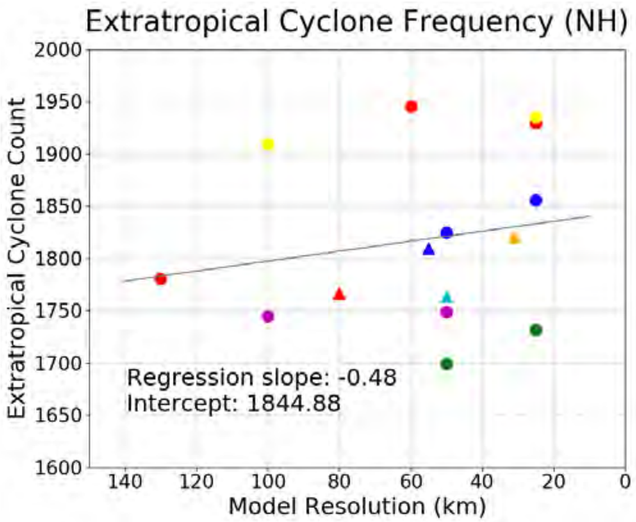
Shoshiro Minobe[1,*], Jiaxiang Gao[1], Malcolm Roberts[2], Rein Haarsma[3], Dian Putrasahan[4], Christopher Roberts[5], Enrico Scoccimarro[6], Laurent Terray[7], Pier Luigi Vidale[8]

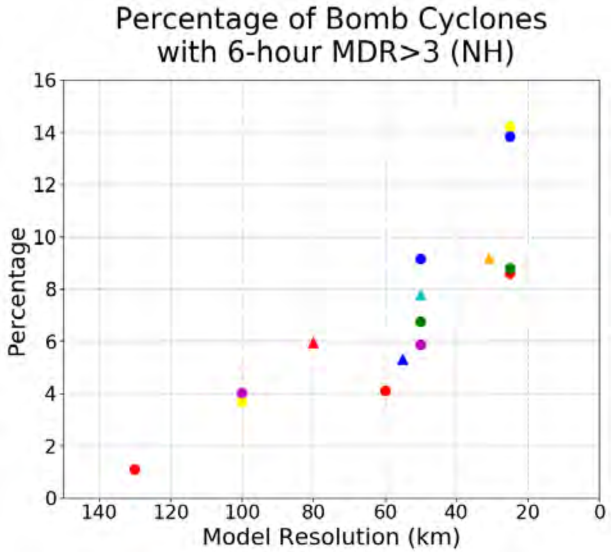
1. Hokkaido University, Japan (minobe@sci.hokudai.ac.jp), 2. UK Met Office, 3. Royal Netherlands Meteorological Institute, Netherlands, 4. Max Planck Institute for Meteorology, Germany, 5. ECMWF, UK, 6. CMCC, Italy, 7. CERFACS, France, 8. University of Reading, UK



Number of bomb cyclones per year at the position of the maximum deepening on 1°×1° box







●: HadGEM3-GC31
●: ECMWF-IFS
●: EC-Earth3
●: MPIESM-1-2
●: CMCC-CM2

▲: ERA-Interim
▲: JRA-55
▲: MERRA2
▲: ERA5

Larger number and more rapidly developing bomb cyclones in high-res models.

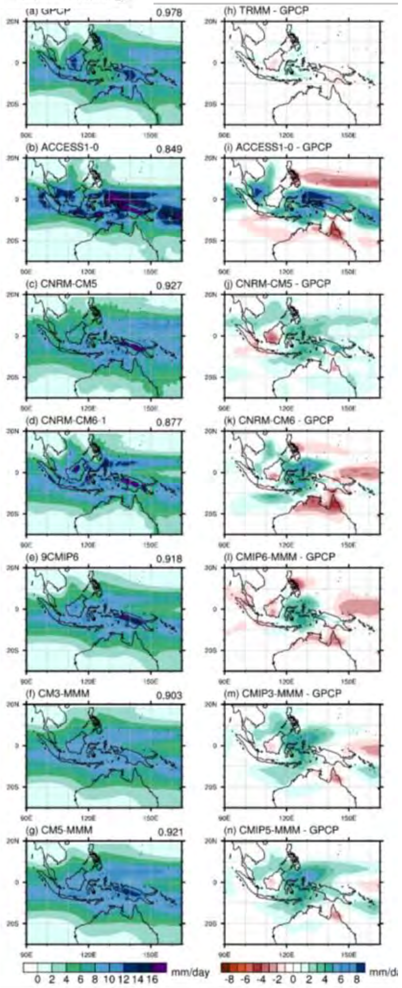
Australian Government
Bureau of Meteorology

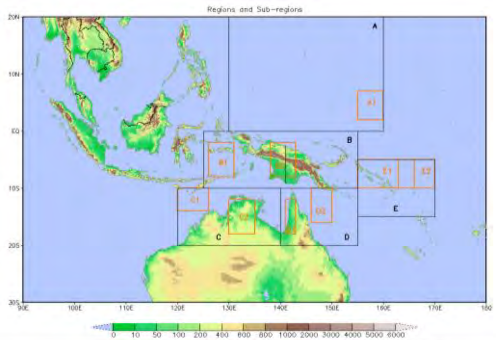
Earth Systems and Climate Change Hub
National Environmental Science Programme

Temporal and spatial intermittency of sub-daily precipitation in Australian monsoon and maritime continent linked to GCM precipitation biases

Aurel Moise[1], Gill Martin[2] and Nicholas Klingamann[3]

[1]Bureau of Meteorology, Melbourne, Australia [2]Met Office, Exeter, UK [3]NCAS, University of Reading, UK





- This work explores the wide range of sub-daily rainfall characteristics in models in order to link back the bias we so often see in models at longer time and spatial scales
- Diagnostic package ASoP was developed recently to study time step and grid point rainfall from models v observation (paper-1) and then applied across a modelling framework (paper-2)
- Mainly to inform model development, but also valuable for model evaluation
- This study: applying the tools within a region of known biases (MC and tropical AUS) to observation and CMIP5 models (part of paper-3)

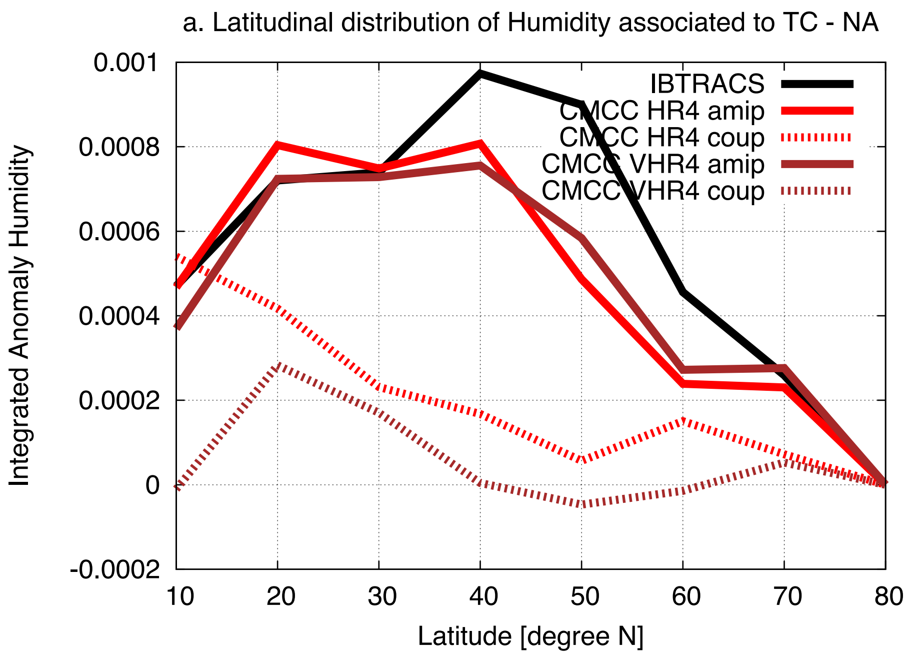
Rainfall climatologies and biases in coupled GCMs:
Observations:
GPCP (1995 – 2014)
TRMM (1998 – 2014)

ACCESS1-0
CNRM-CM5
CNRM-CM6-1
CM6-EMM (no=9)
CM3-EMM
CM5-EMM

CMP5 models use the older reference comparison period (1986-2005) and CMIP6 use the newer period (1995-2014)

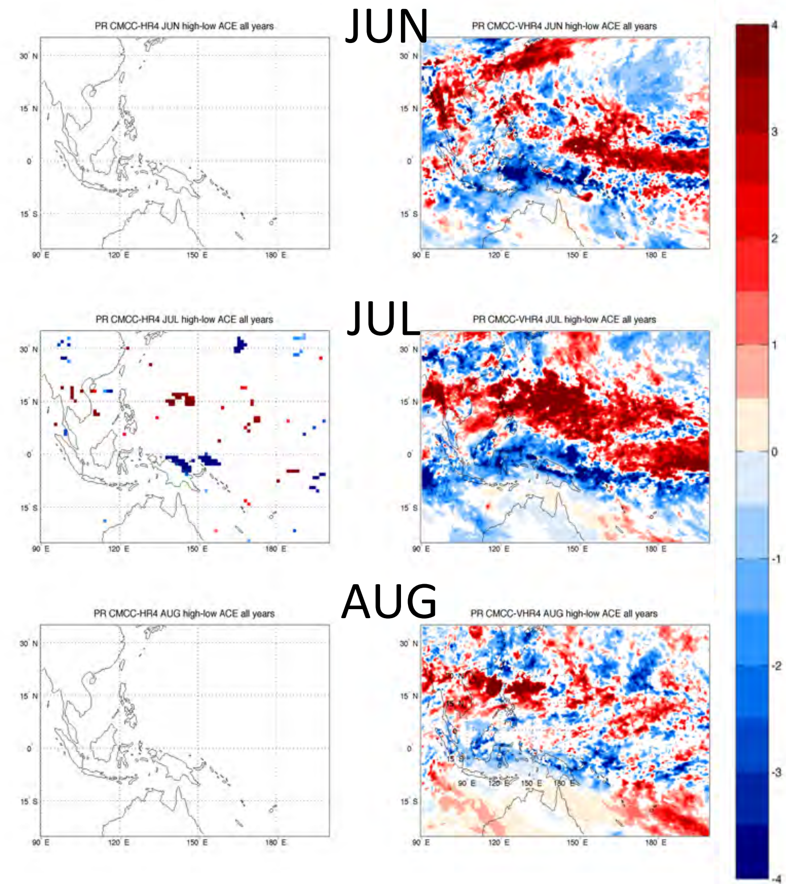
Moisture Transport associated to Tropical Cyclones

North Atlantic



HighresSST simulations shows more realistic latitudinal distribution of specific humidity anomaly compared to coupled simulations. Besides, change in resolution is not linked to better performances

Maritime Continent



VHR Model: realistic TCs over WNP induce less precipitation in high ACE years (Same as observed). HR model: no realistic TC activity and no signal.

Daniele Peano, E. Scoccimarro, A. Bellucci, A. Cherchi, A. D'Anca, F. Antonio, S. Fiore, S. Gualdi **Poster 4-P21**

Quantifying tropical cyclone rainfall and size in high resolution climate simulations

Kevin A. Reed, Alyssa M. Stansfield, Colin M. Zarzycki and Paul A. Ullrich

Stony Brook University

U.S. DEPARTMENT OF ENERGY | Office of Science

HYPERION
UNDERSTANDING HYDROCLIMATE DATA WITH USE-INSPIRED METRICS

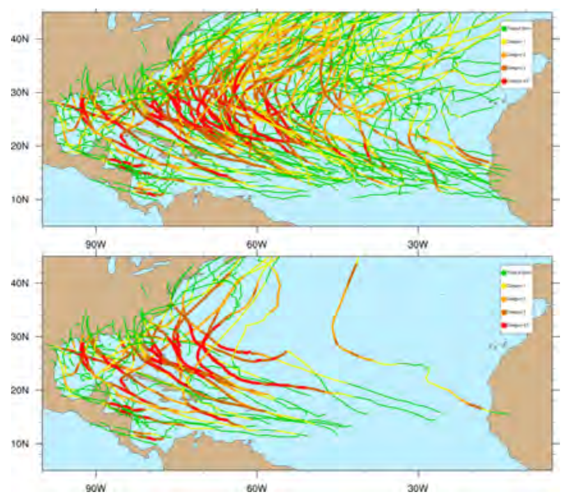
Extreme Precipitation:

Understand the extreme rainfall associated with landfalling tropical cyclones.

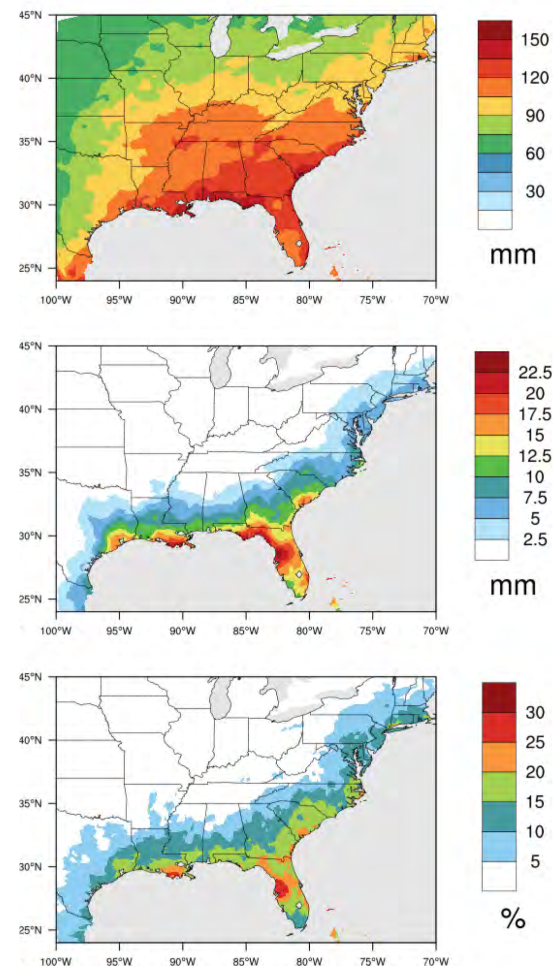
Develop Advanced Metrics:

Needed for evaluation of high-resolution climate models (e.g., HighResMIP).

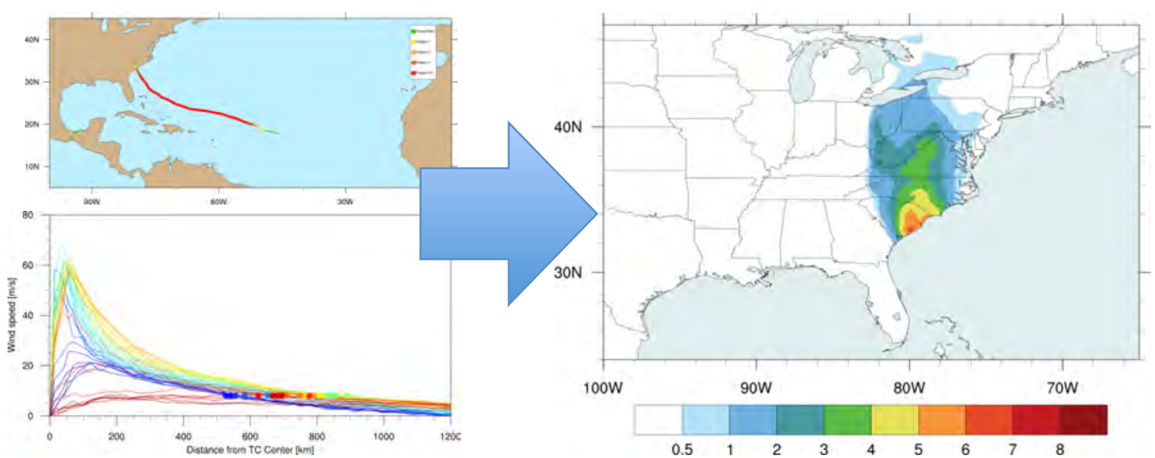
CAM5 Tracks & Landfalls



Extreme Rainfall & Storm Contribution

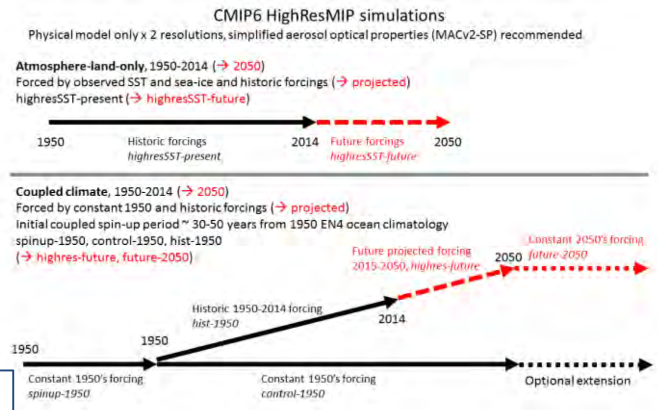


Example CAM5 Storm



Coordinated Global High Resolution Climate Modelling – PRIMAVERA and HighResMIP

Malcolm Roberts[1], Pier Luigi Vidale[2], Benoit Vanniere[2], Christopher Roberts[3], Jon Seddon[1], and PRIMAVERA project partners[4]
[1]Met Office; [2]NCAS-Climate, University of Reading; [3]ECMWF; [4]CMCC, BSC, KNMI, SMHI, MPI-M, NERC-NOC, CERFACS, AWI, UCLouvain, UOxford, ISAC-CNR, ULeeds, UStockholm, STFC, predictia, DKRZ, Meteo-Romania.

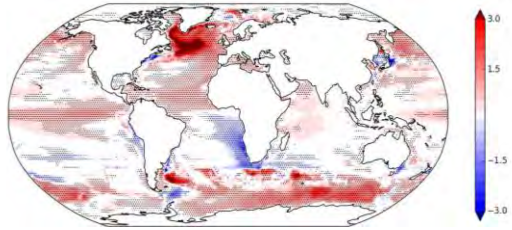


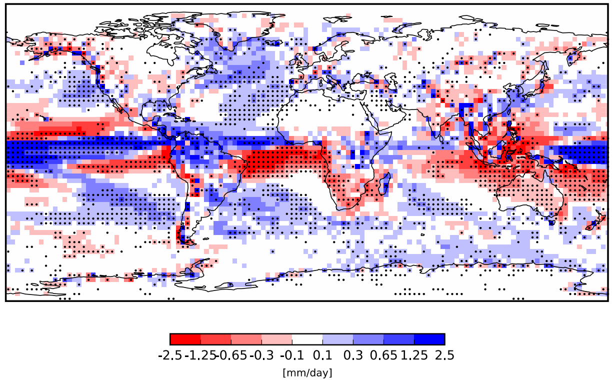
CMIP6 HighResMIP – impact of horizontal resolution on climate simulation – biases in mean, variability, extremes – hopeful that ~20 groups internationally will complete simulations

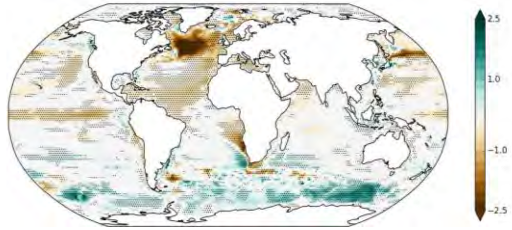
H2020 PRIMAVERA – global and regional processes important for European climate simulation, making use of HighResMIP simulations from European groups (7 models)

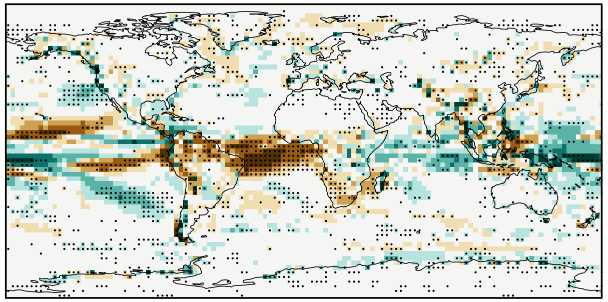
#Ensemble members/resolution needed for interannual variability of TCs?

Multi-model biases



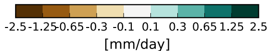


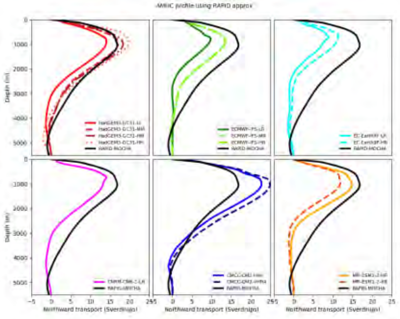


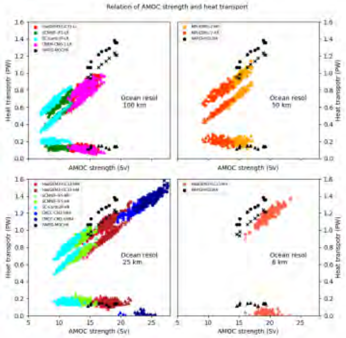


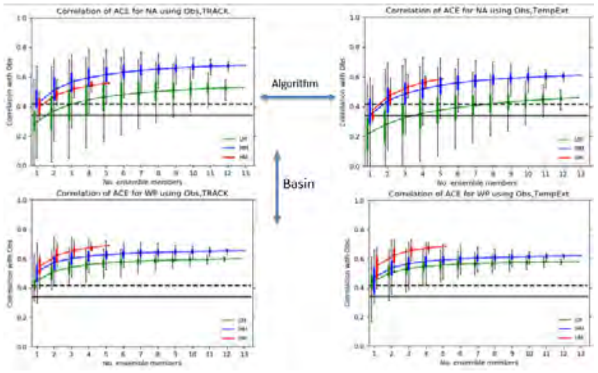
SST

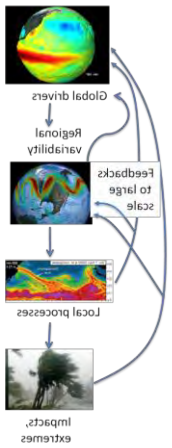
precipitation











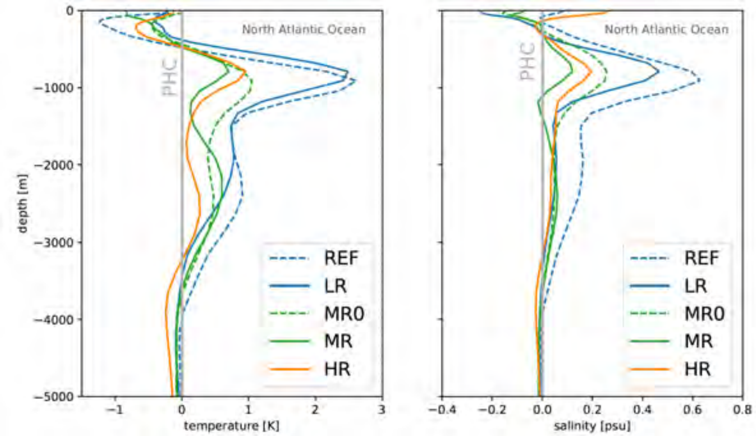
Ocean circulation and heat transport

Co-funded by the European Union

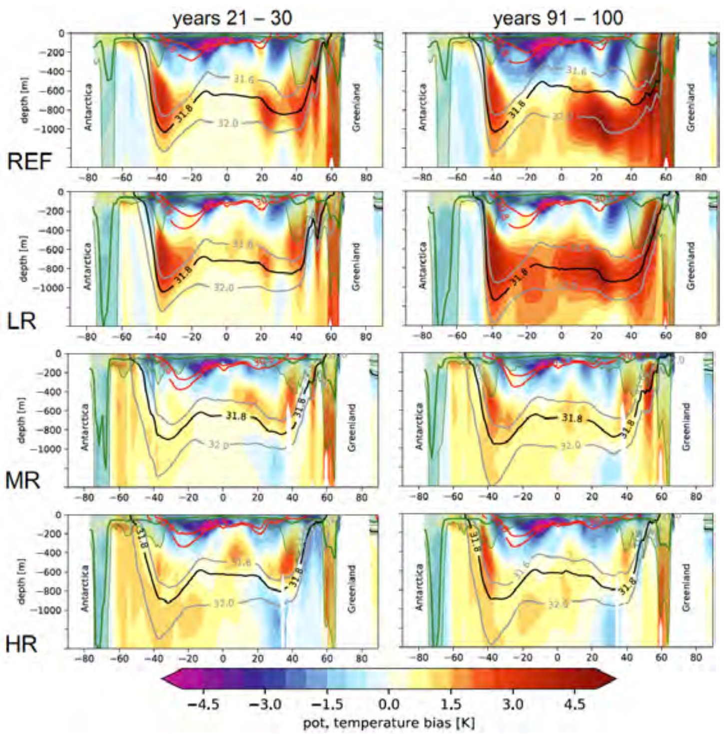
PRIMAVERA

Sensitivity of Atlantic Ocean deep biases to horizontal resolution in prototype CMIP6 simulations

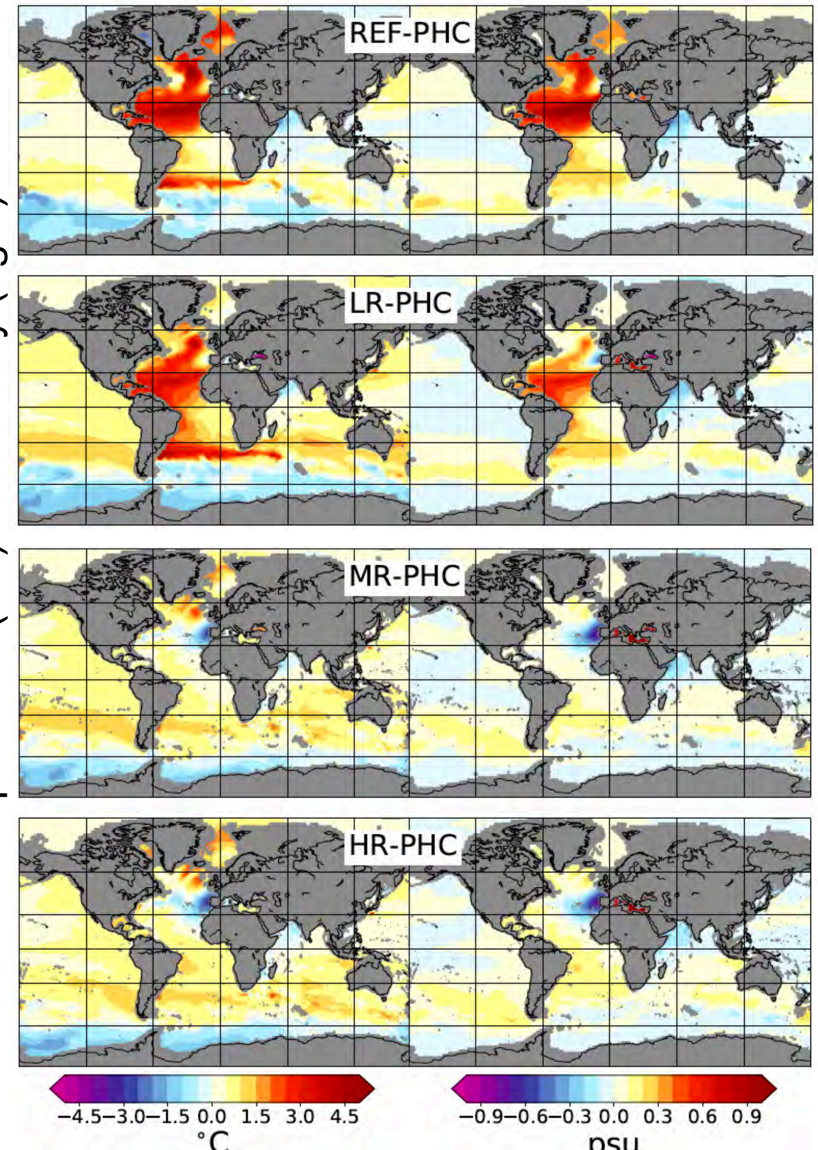
Profiles of temperature (left) and salinity (right) for the North Atlantic



Meridional section at 30.5W for the temperature bias



1000 m temperature (left) and salinity (right) bias

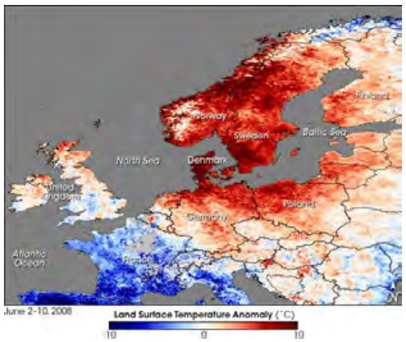


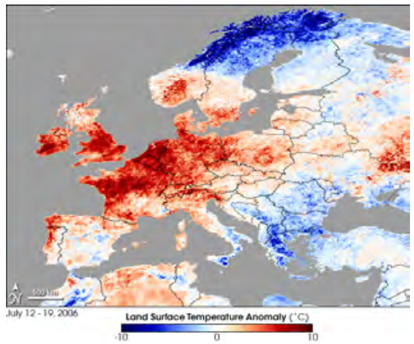
HELMHOLTZ ASSOCIATION

Contrasting seasonality in extreme weather changes over Europe during 1950-2017

Session 4
P25

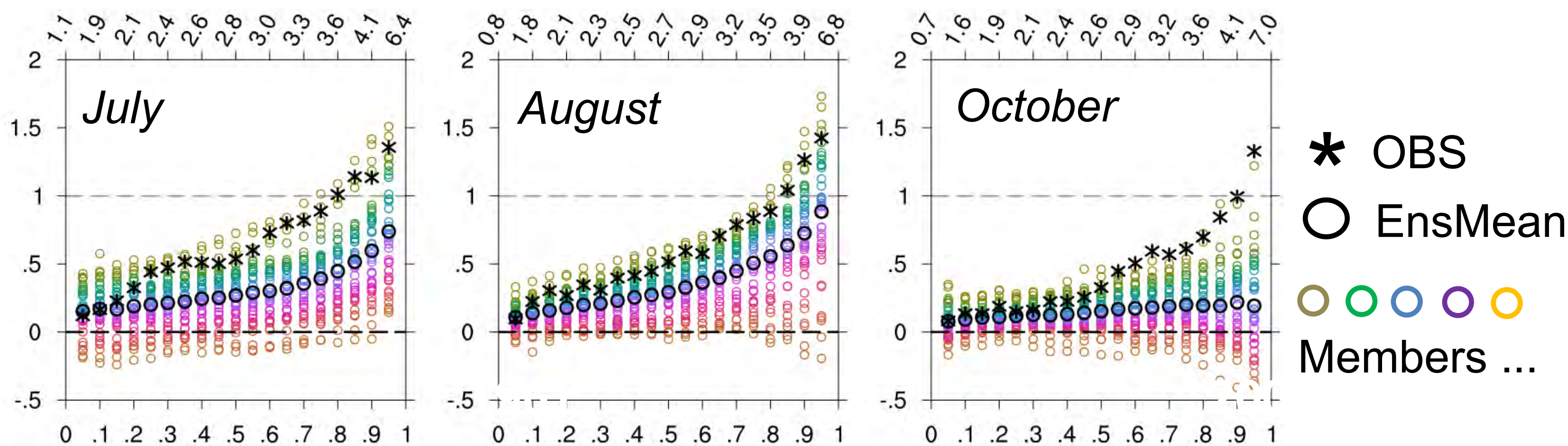
Laurent Terray





- **Daily index (Area-average of |Tx|)**
- **Significant changes in summer**
- **Attribution based on:**
  - Observations
  - Models: Large ensemble & HiResMIP

Quantile regression: trend °C/68 years



Drivers & mechanisms : GHG, AER, AMV, Arctic ?

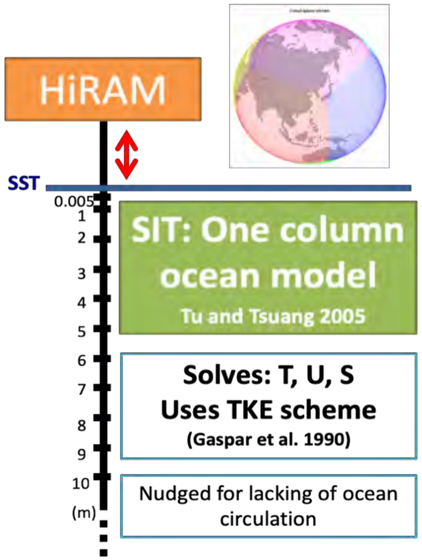
Projection of Tropical Cyclone Activity in the Western North Pacific Using a Single Column Ocean Coupled Model

Chia-Ying Tu[1], Huang-Hsiung Hsu[1], Shian-Jiann Lin[2]

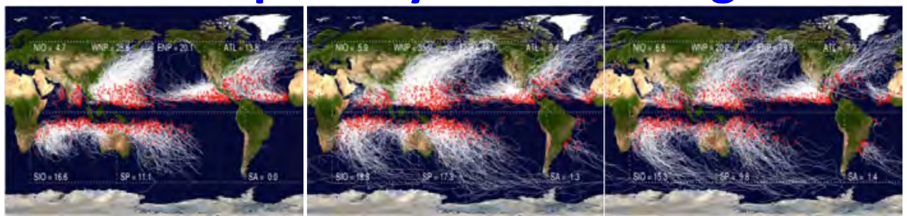
1. Research Center for Environmental Changes, Academia Sinica, Taiwan

2. GFDL, NOAA, USA

- *HiRAM-SIT for HighResMIP's experiments.*
- *Simulated SST from HiRAM-SIT was nudged to CMIP5 1-deg SST to avoid climate drift.*
- *Significantly weakened TC activity in the WNP in the future.*
- *The anticyclonic response is the largest in this monsoon trough (cyclonic) region.*

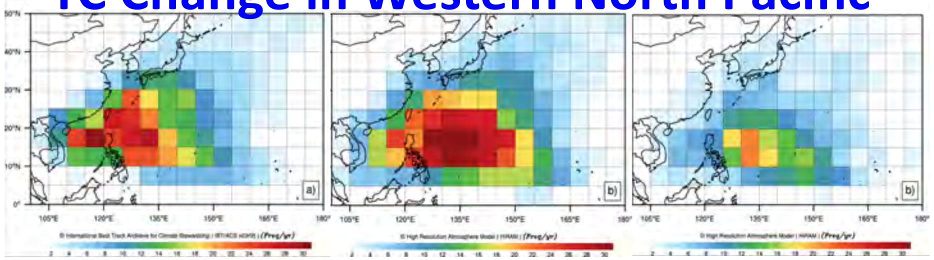


Global Tropical Cyclones Change



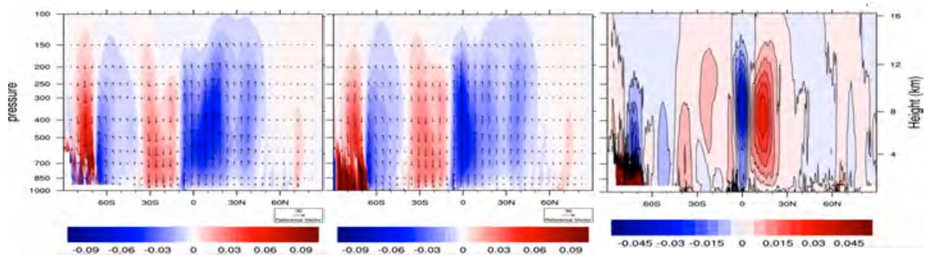
(⬉) IBTrACS (⬆) 1990~2010 (⬈) 2030~2050

TC Change in Western North Pacific

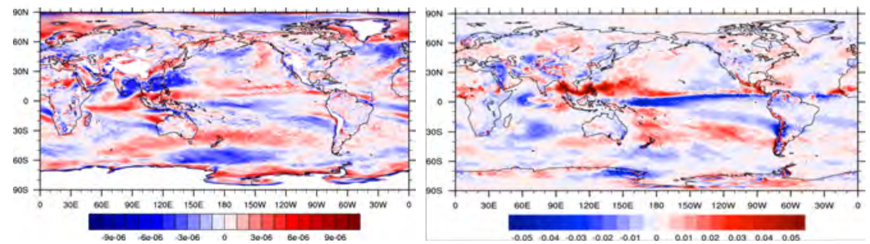


(⬉) IBTrACS (⬆) 1990~2010 (⬈) 2030~2050

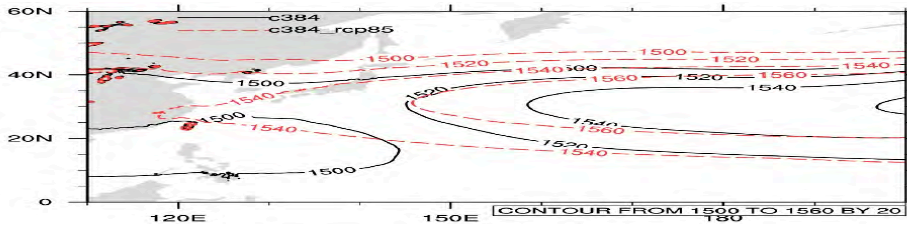
Process Leading the TC Activity Reduction



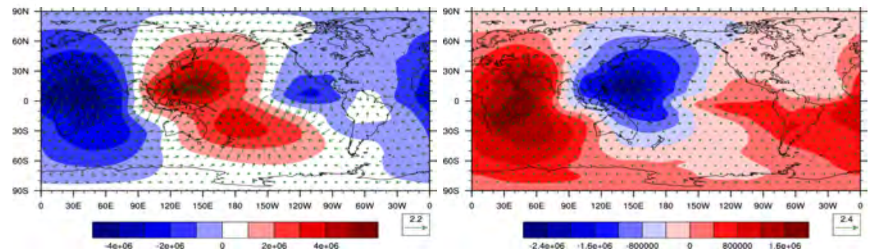
JJA meridional vertical velocity at 500hPa in the Western Pacific. (⬉) current; (⬆) future; (⬈) diff (future-current).



ASO (⬉)vorticity diff. (⬈) 500hPa omega diff. (future-current).



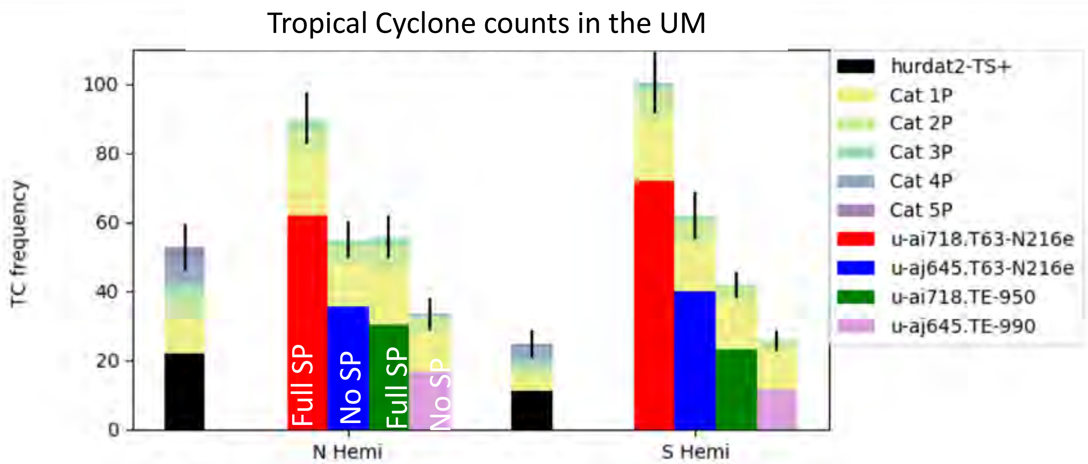
ASO 500hPa geopotential height. (Black: current; Red: future).

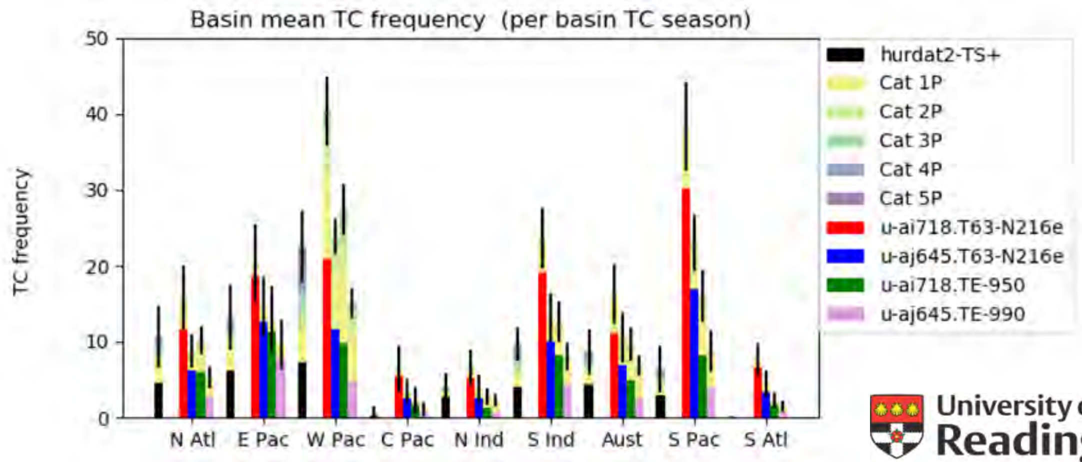


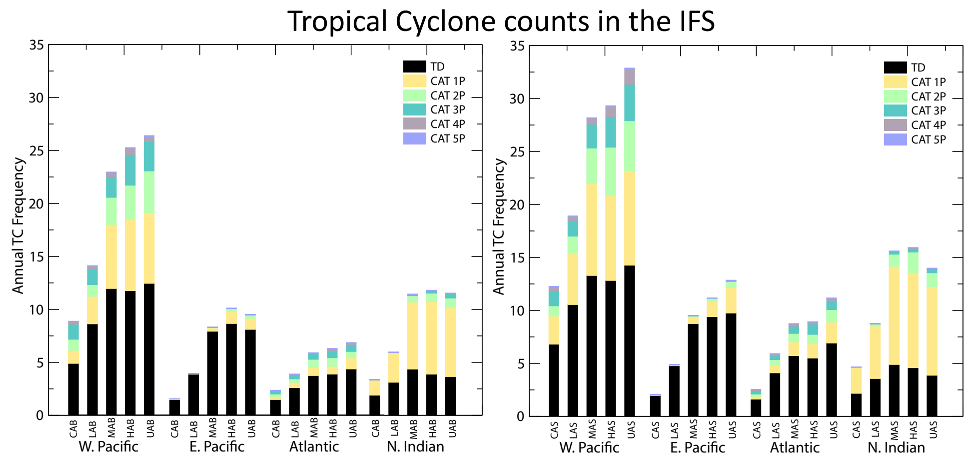
ASO velocity potential diff. (future-current). (⬉) 200hPa; (⬈) 850hPa.

The role of Stochastic Physics and model resolution for the simulation of Tropical Cyclones in AGCMs

Pier-Luigi Vidale (1,3), Kevin Hodges (3,1), Malcolm Roberts (2), Paolo Davini(4), Antje Weisheimer(5), Kristian Strommer(5) and Susanna Corti(4)
(1) NCAS-Climate, University of Reading, UK, (2) Met Office Hadley Centre, Met Office, Exeter UK, (3) University of Reading, Meteorology, Reading, United Kingdom
(4) CNR Institute of Atmospheric Sciences and Climate, Bologna, Italy (5) University of Oxford, Department of Physics and NCAS, Oxford, United Kingdom







Both models show sensitivity to the use of Stochastic Physics.

At all resolutions, models with Stochastic Physics simulate 30-50% more TCs, as well as an increase in ACE.

Stochastic Physics appears to play a larger role at low resolution, as well as affecting the lower category storms more strongly than the upper categories.

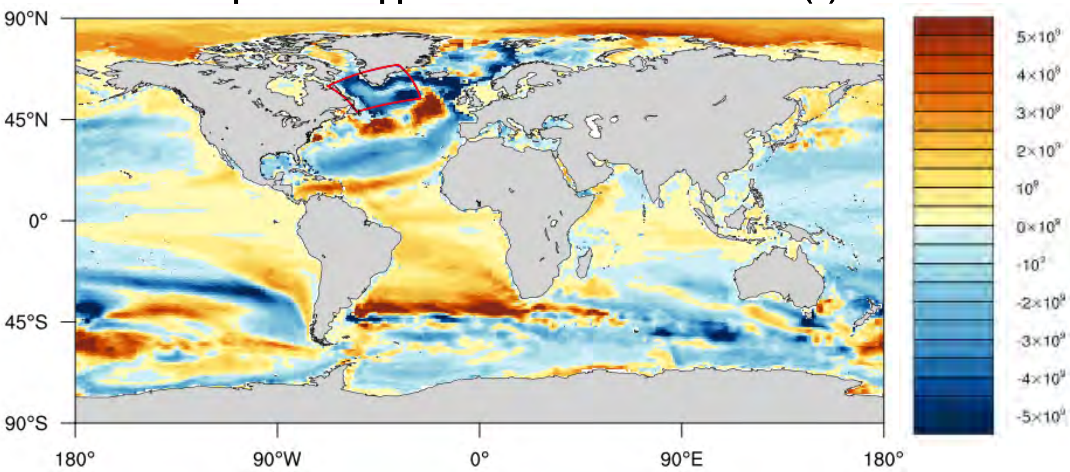
4-P28: Role of ocean mesoscale eddies for the response of the climate system to strong greenhouse gas forcing

von Storch, J.-S., **Putrasahan, D. A.**, Lohmann, K., Jungclaus, J. H., Gutjahr, O., Haak, H.
Max Planck Institute for Meteorology, Hamburg, Germany

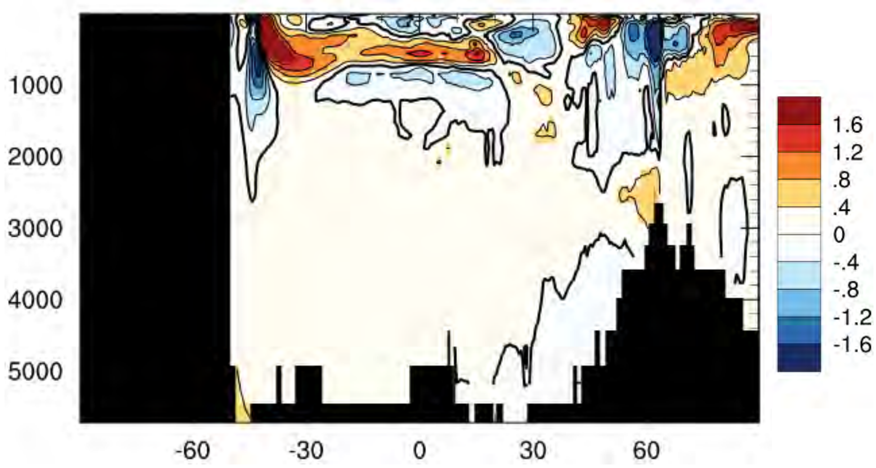
We set up 3 coupled model configurations with different ocean resolution, each having a control and 3 ensemble members of $4xCO_2$ simulations currently integrated to 50 years.

Name	Resolution (ocean/atm)
ER (eddy-resolving)	TP6M/T127 (0.1°/ 1°)
HR (eddy-permitting)	TP04/T127 (0.4°/ 1°)
NR (non-eddy resolving)	TP10/T127 (1°/ 1°)

Difference in response of upper 700m ocean heat content (J) in 5th decade



Difference in response of zonal mean temperature over the Atlantic ocean (°C) for the 5th decade



- Eddy-resolving shows small but systematically weaker response of global mean surface temperature to $4xCO_2$ forcing compared to non-eddy resolving.
- We see regional differences in upper ocean heat content response, particularly in the Atlantic ocean.
- In the South Atlantic, eddy-resolving takes up more heat (red) than non-eddy resolving, while the North Atlantic subpolar gyre region, it is the opposite.
- We perform a heat budget analysis over the subpolar gyre region and separate the contribution of mean vs eddy heat fluxes in order to understand the difference in the response seen.

Max-Planck-Institut für Meteorologie

contact: dian.putrasahan@mpimet.mpg.de

PRIMAVERA

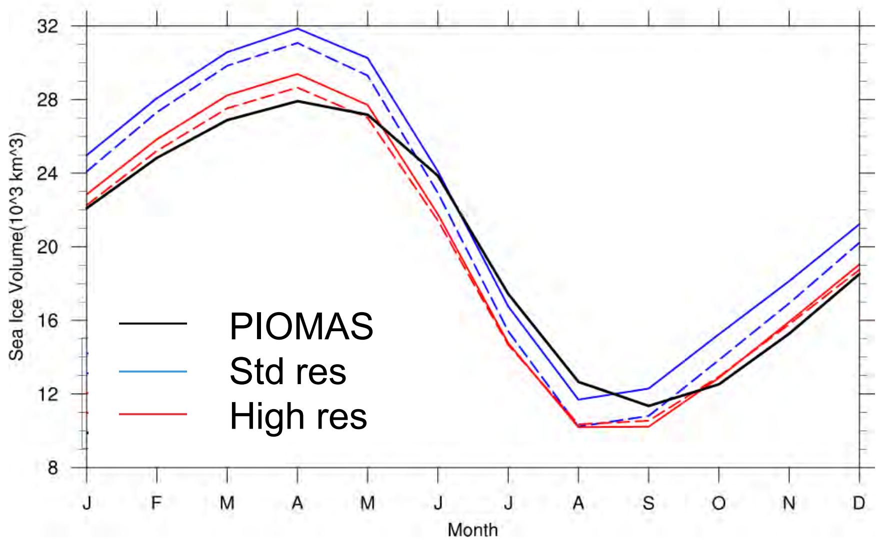
MAX-PLANCK-GESELLSCHAFT

S4 P30: Improved melt ponds in climate models

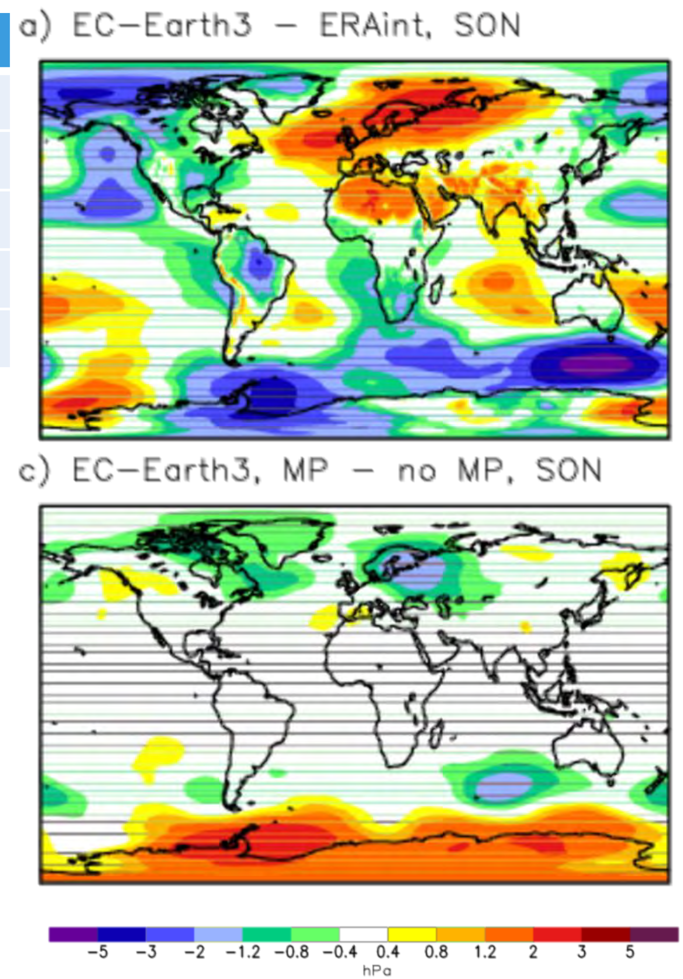
Albedo where Arctic sea ice

	April	May	June	July	August
NSIDC	0.716	0.720	0.628	0.512	0.476
CTRL_STD	0.776	0.765	0.694	0.570	0.546
MELT_STD	0.774	0.759	0.688	0.560	0.548
CTRL_HR	0.763	0.754	0.665	0.541	0.520
MELT_HR	0.767	0.756	0.678	0.562	0.546

Arctic sea ice volume



MSLP bias and change



Bottom Potential Temperature and Sea Ice Extent in the Southern Ocean

Comparison of

- CMIP5 vs CMIP6
- Resolutions

See Poster S4 P31