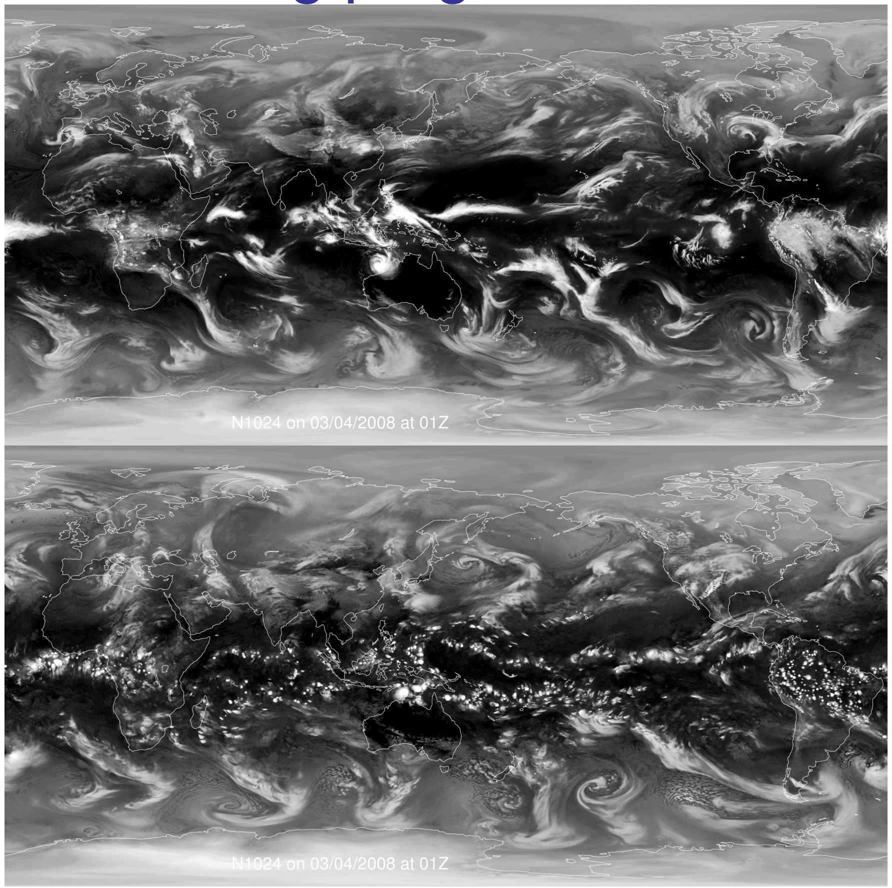
Met Office | NATURAL ENVIRONMENT RESEARCH COUNCIL | A partnership in weather and climate research

Joint Weather and Climate Research Programme

PRACE-UPSCALE

and the UK's high-resolution climate modelling programme



National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL
University of Reading

Pier Luigi Vidale,

Marie-Estelle Demory, Reinhard Schiemann,
Jane Strachan

Malcolm Roberts, Matthew Mizielinski,

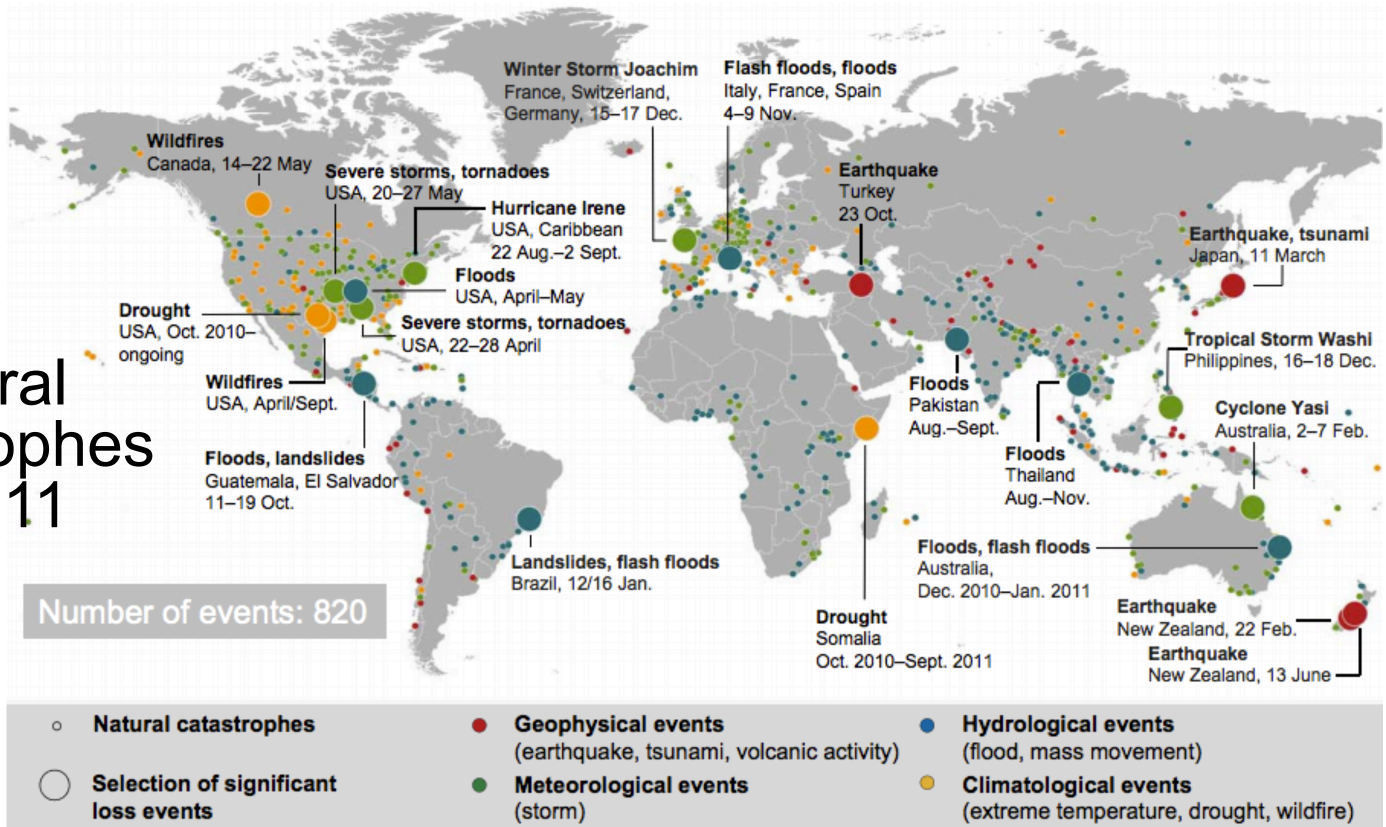
Lizzie Kendon, + Met Office

(with thanks to the many MO groups

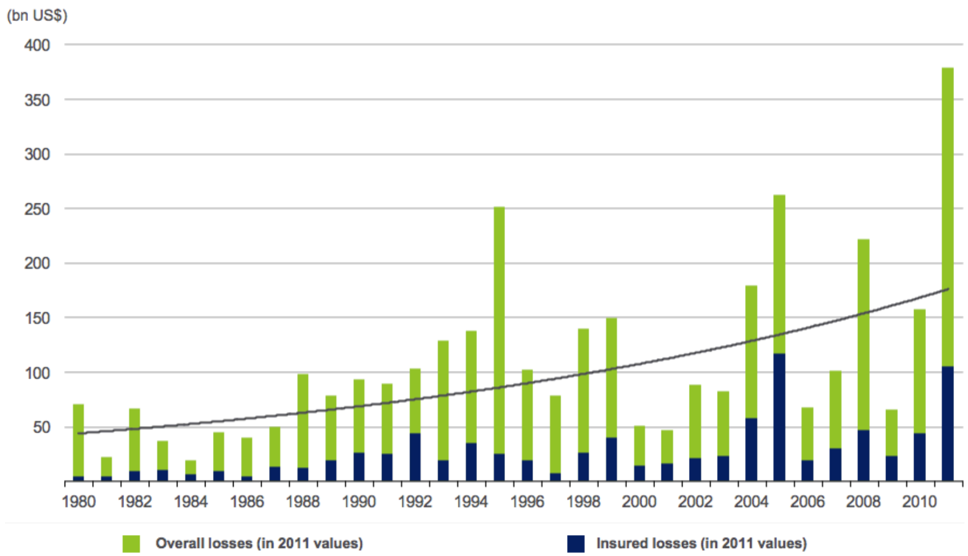
Involved in model development and elsewhere)

IS-ENES2, Toulouse, Feb 2013

Natural Catastrophes of 2011



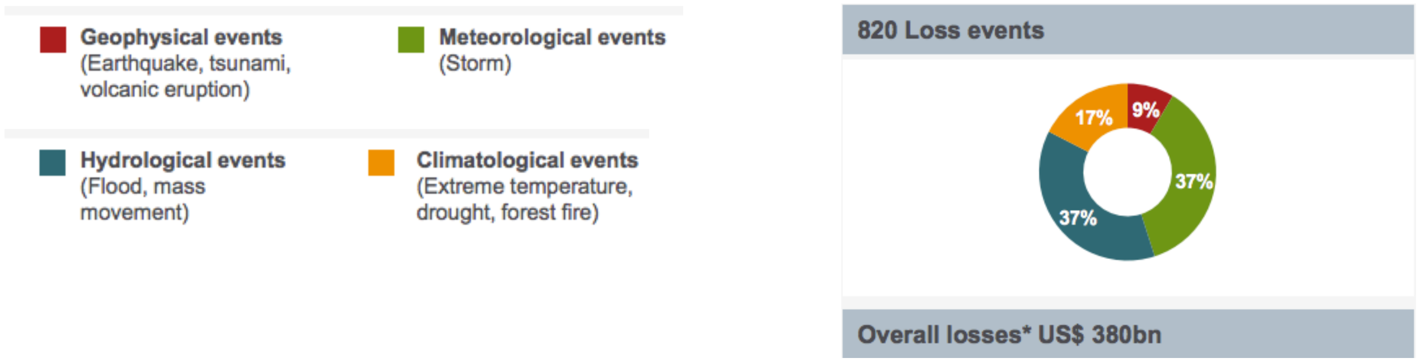
Comparing 2011 with previous years



Munich Re 2012

Motivations for a **Weather and Climate Hazards Laboratory**:
Economic Impact of Weather-related Natural Catastrophes of 2011

- 2011= costliest year ever in terms of natural catastrophe
- **US$380bn** global economic losses / US$105bn insured losses (Munich Re)
- Although earthquake dominated loss in 2011 (Japan Tsunami prominent), still **90% of the number of natural catastrophes were weather-related**



•Munich Re 2012

- UK insurance and UK science share a need to understand the world around us and to understand how it is changing.
- Need for continuous engagement between the insurance industry and the scientific community to ensure industry has the best possible information to increase its market resilience to W&C risk

Knowledge Transfer Partnerships

Willis Research Network

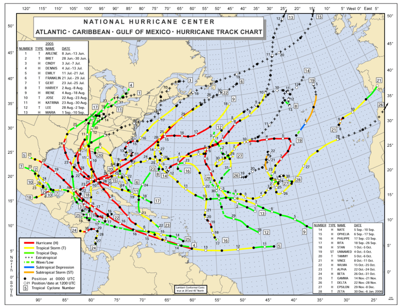
Outline

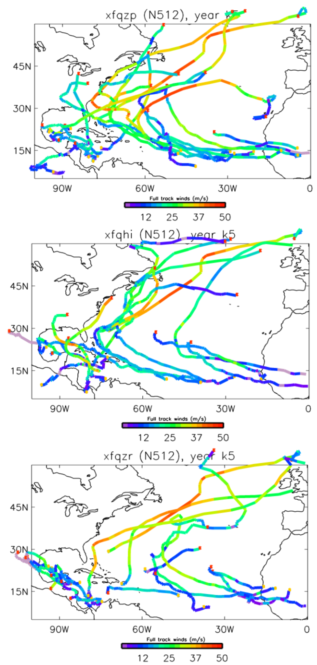
- UK high-resolution climate models
- The PRACE-UPSCALE grant
  - Scalability achievements
- Science highlights:
  1. The global hydrological cycle at high-resolution
  2. Hurricanes in the climate system
  3. European heat waves
  4. The diurnal cycle of precipitation in GCMs
- New high-resolution model developments

The PRACE-UPSCALE Project

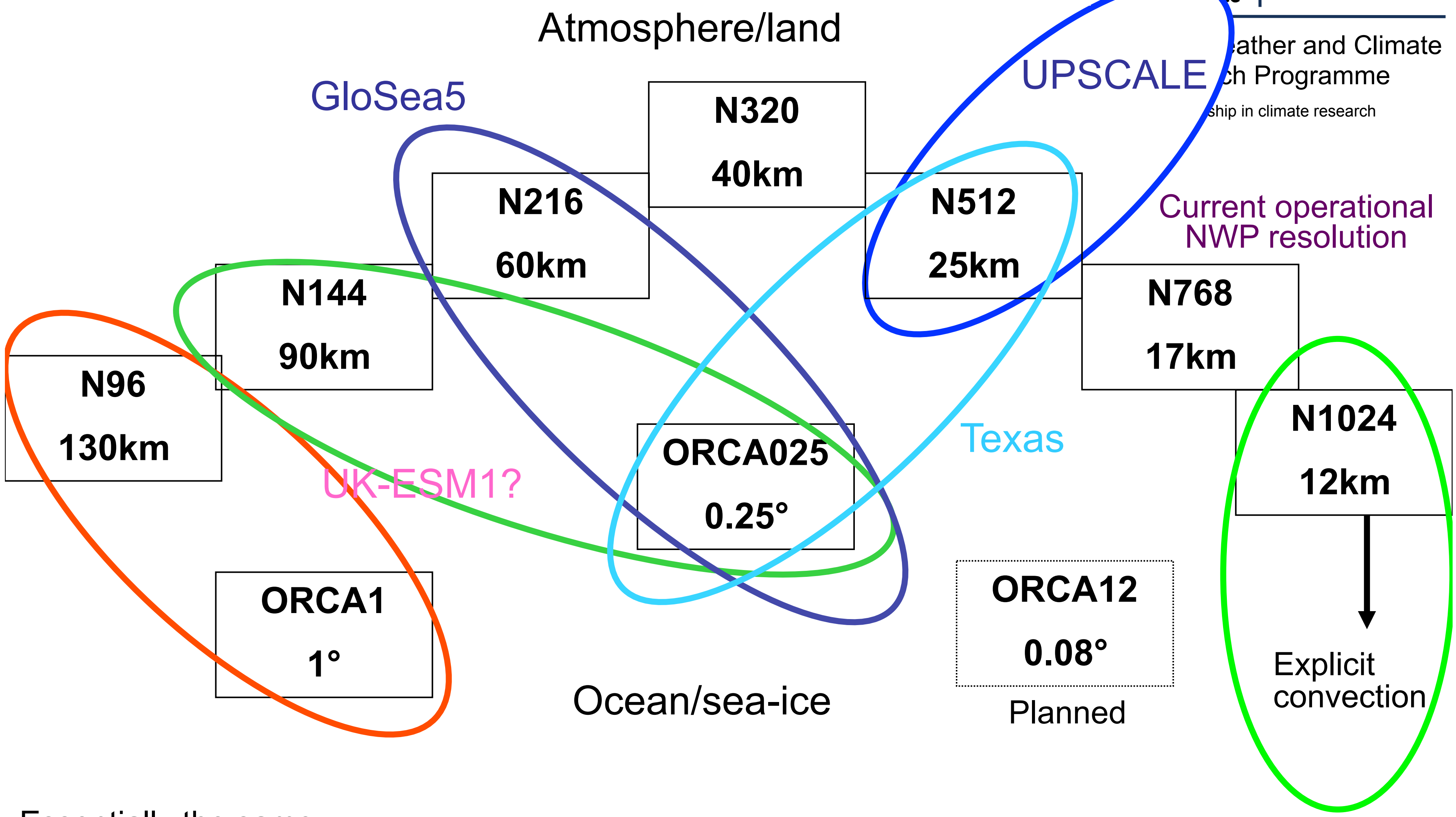
UK on PRACE - weather resolving Simulations of Climate for globAL Environmental risk

- current “numerical mission” of the JWCRP High-resolution climate modelling team
- 144 million core hours (equivalent to roughly half the HECToR facility) awarded for 1 year by PRACE (Partnership for Advanced Computing in Europe)
- HadGEM3-A multi-decadal simulations at N96 (130 km) to N512 (25 km), shorter experimental simulations at N1024 (12 km)
- present climate simulations
  - forced with OSTIA SSTs
  - 1985-2011 (27 years)
  - 5 ensemble members
- future climate simulations
  - 3 ensemble members à 27 years
  - following RCP8.5
  - SST: daily OSTIA + HadGEM2-AO RCP8.5 2100 ΔSST
- UPSCALE output available on JASMIN@CEDA





MetUM global atmosphere/coupled model climate configurations in use



Essentially the same physics/dynamics parameters used throughout model hierarchy

Project to assess impact of global explicit convection

Setup and "best practice" core counts on different architectures

Resolution		Number of cores				Notes
		NEC SX6	IBM P6	IBM P7	CRAY XE6	
N96 = 135km HG1-L38 HG3-L85		1*8 1*8	96	128		For HadGEM1: ES processors about 4x more powerful than P7
	Turnaround	1 sypd 10smo/day	3 sypd	3.5 sypd (EndGame)		
N216 = 60km HG1-L38 HG3-L85		11*8	192	3*32	1024	For HadGEM1: ES processors about 4x more powerful than P7
	Turnaround	1 sypd	8 smo/day	5 smo/day	13smo/day	
N512= 25km				64*32 40*32 (EG) 200*32 (L70 EG)	9408	
	Turnaround			7 smo/day 5.7 smo/day 2 sypd	6 smo/day	Ensemble of 5 runs, concurrent, up to 47K cores
N1024 = 12km				74*32		
	Turnaround			1.2 smo/day		

Climate System Science: precipitation

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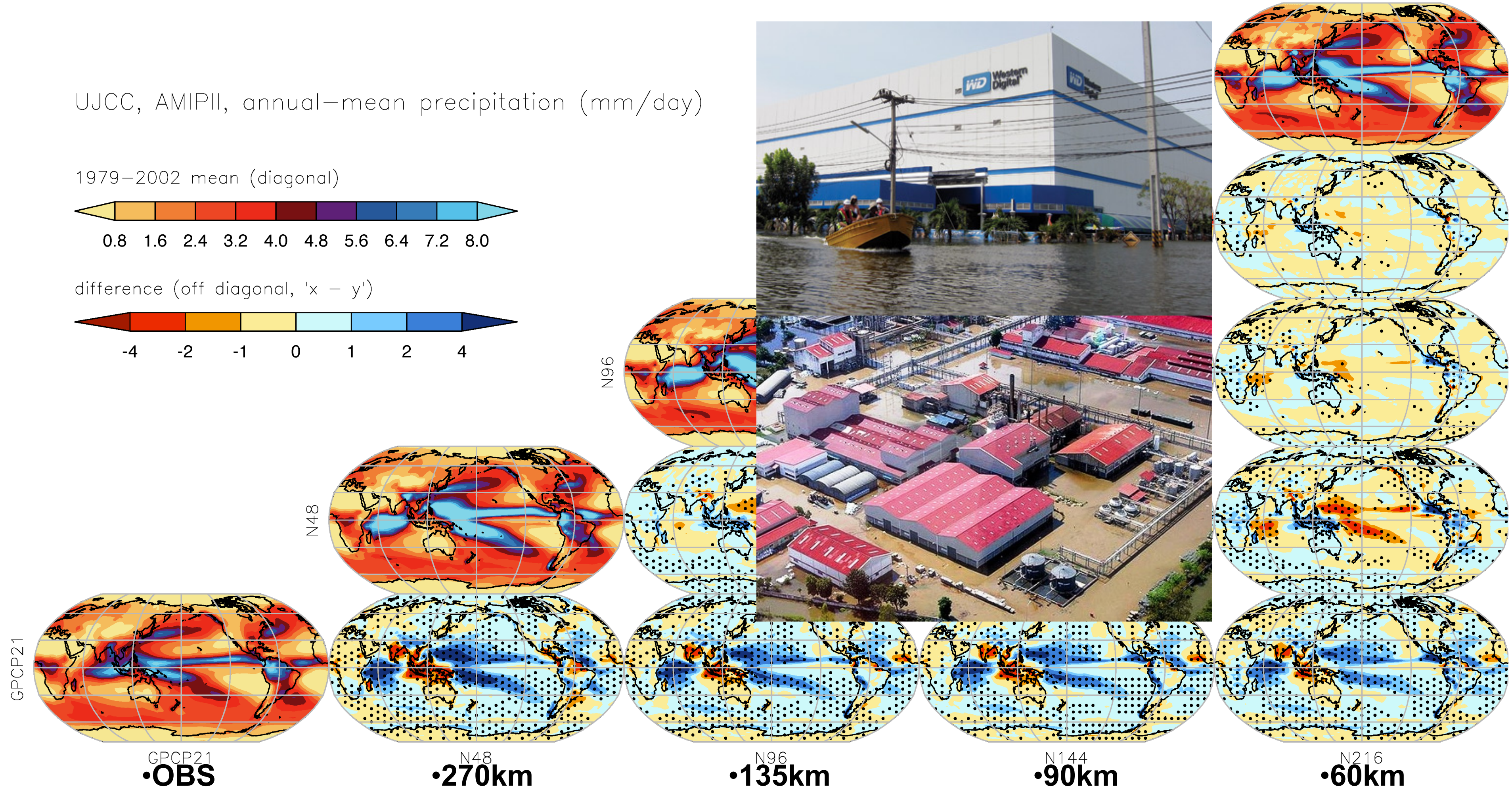
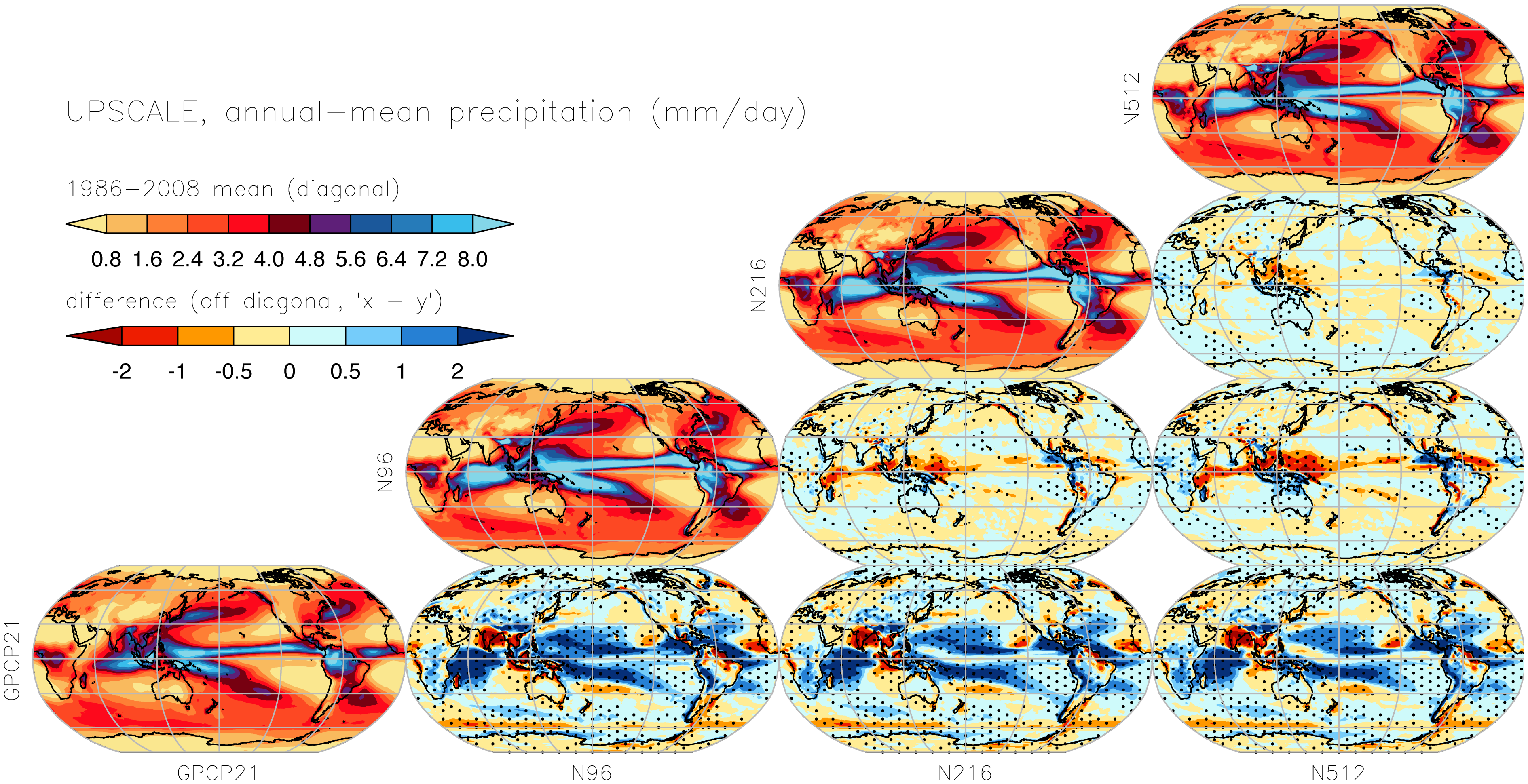
- Precipitation around the globe: the role of model resolution in reducing HadGAM1 GCM bias



R. Schiemann et al., Clim. Dyn., submitted

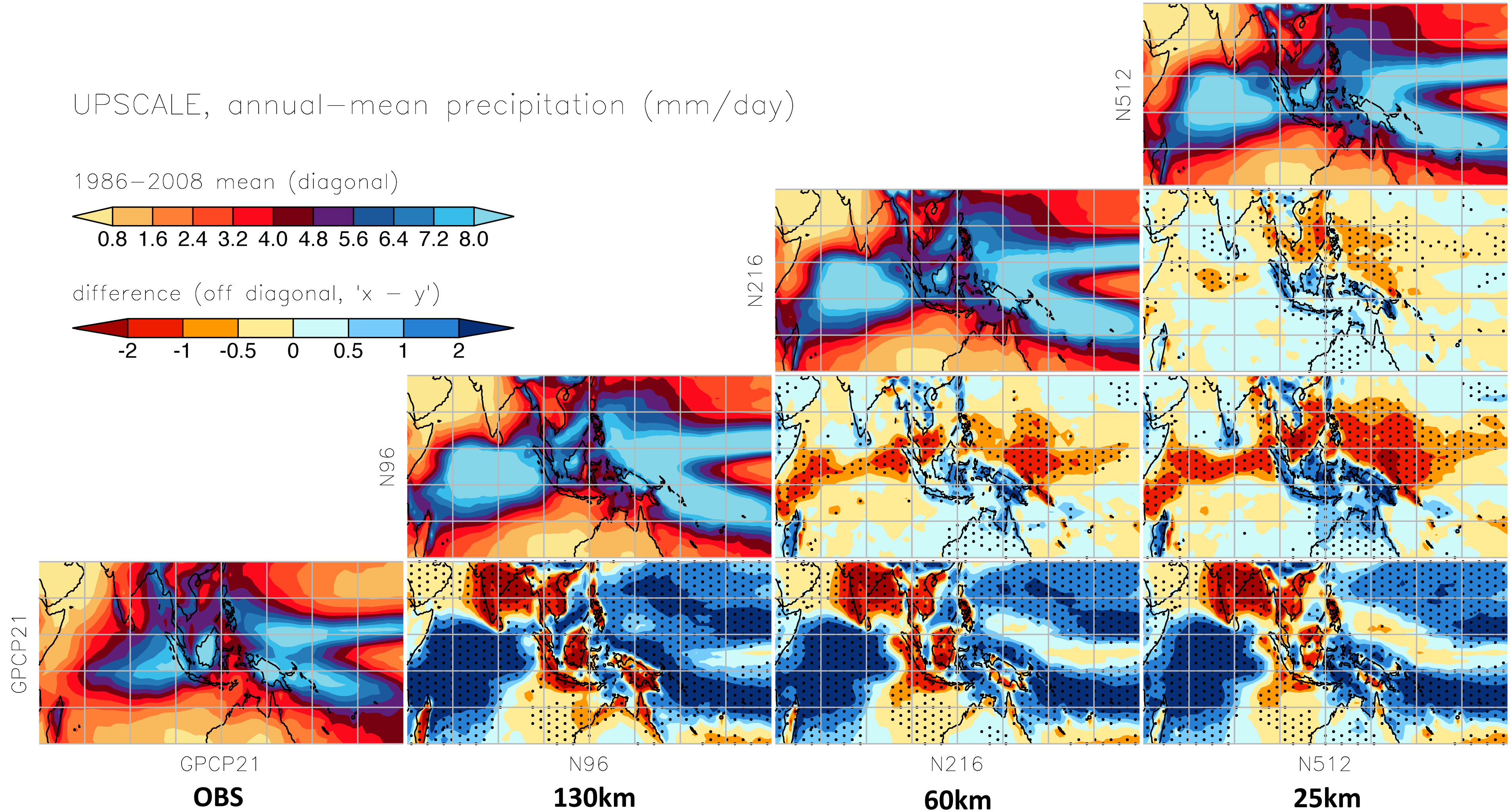
Tropical precipitation biases (HadGAM3)



OBS | 130km | 60km | 25km

Vidale et al. 2013, Schiemann et al. 2013, in preparation

Tropical precipitation biases (HadGAM3)



Vidale et al. 2013, Schiemann et al. 2013, in preparation

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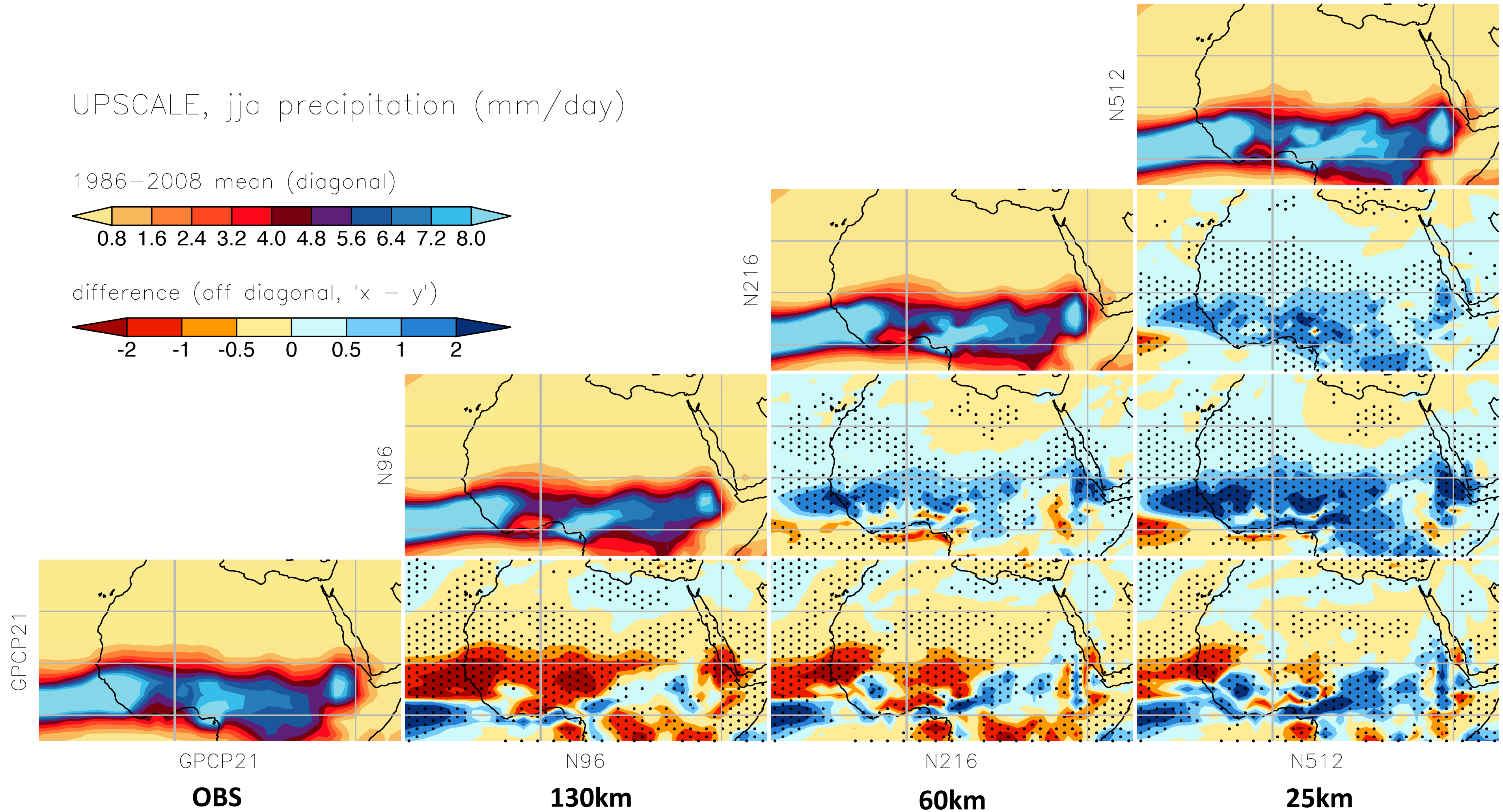

Vidale et al. 2013, Schiemann et al. 2013, in preparation

What changes with resolution?
Hopefully, important things are resolution-invariant.
Global energy budget

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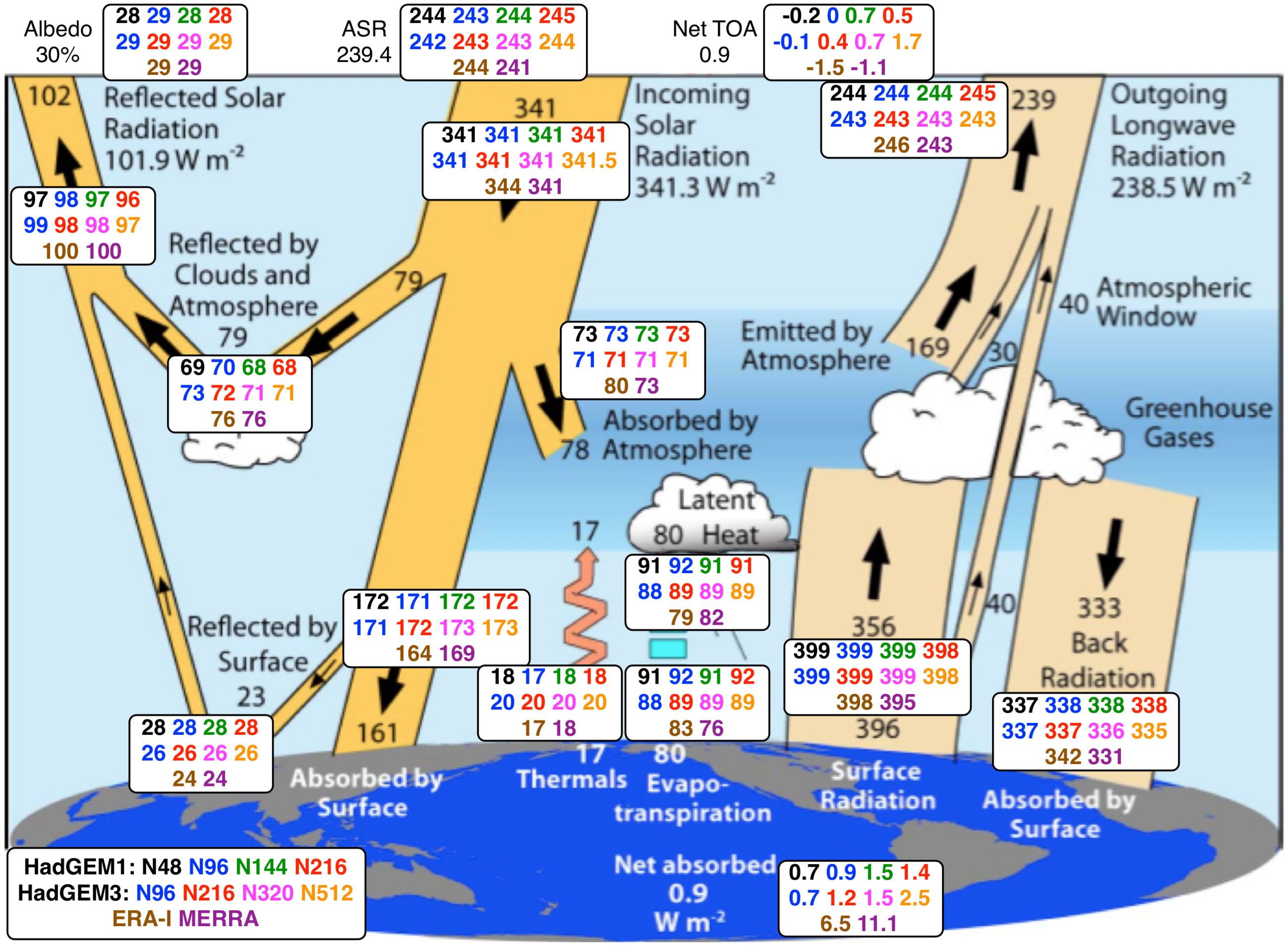

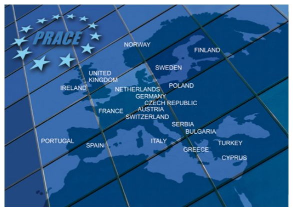

Demory et al., Clim. Dyn., submitted

CSS: the global hydrological cycle

- Classic GCMs too dependent on (poor) physical parameterisations, because of unresolved atmospheric transports.

- Role of <u>resolved</u> sea→land transport is larger and more realistic at high resolution

- Hydrological cycle is more intense at high resolution

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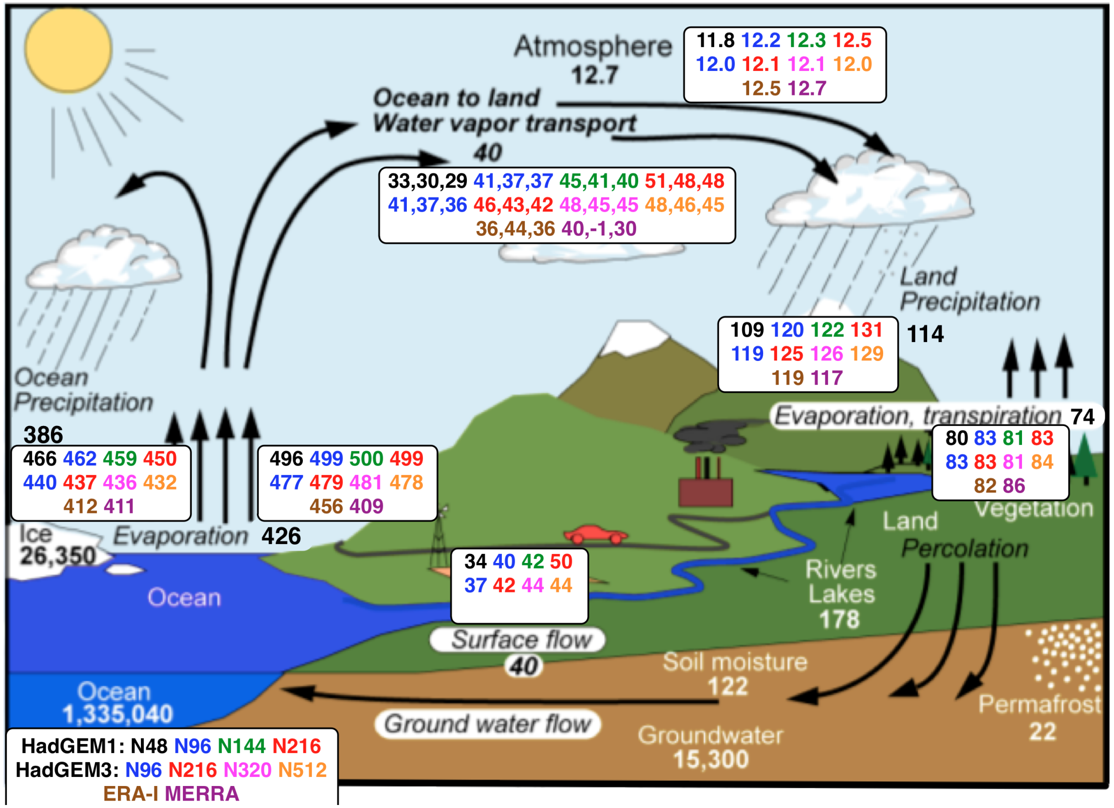
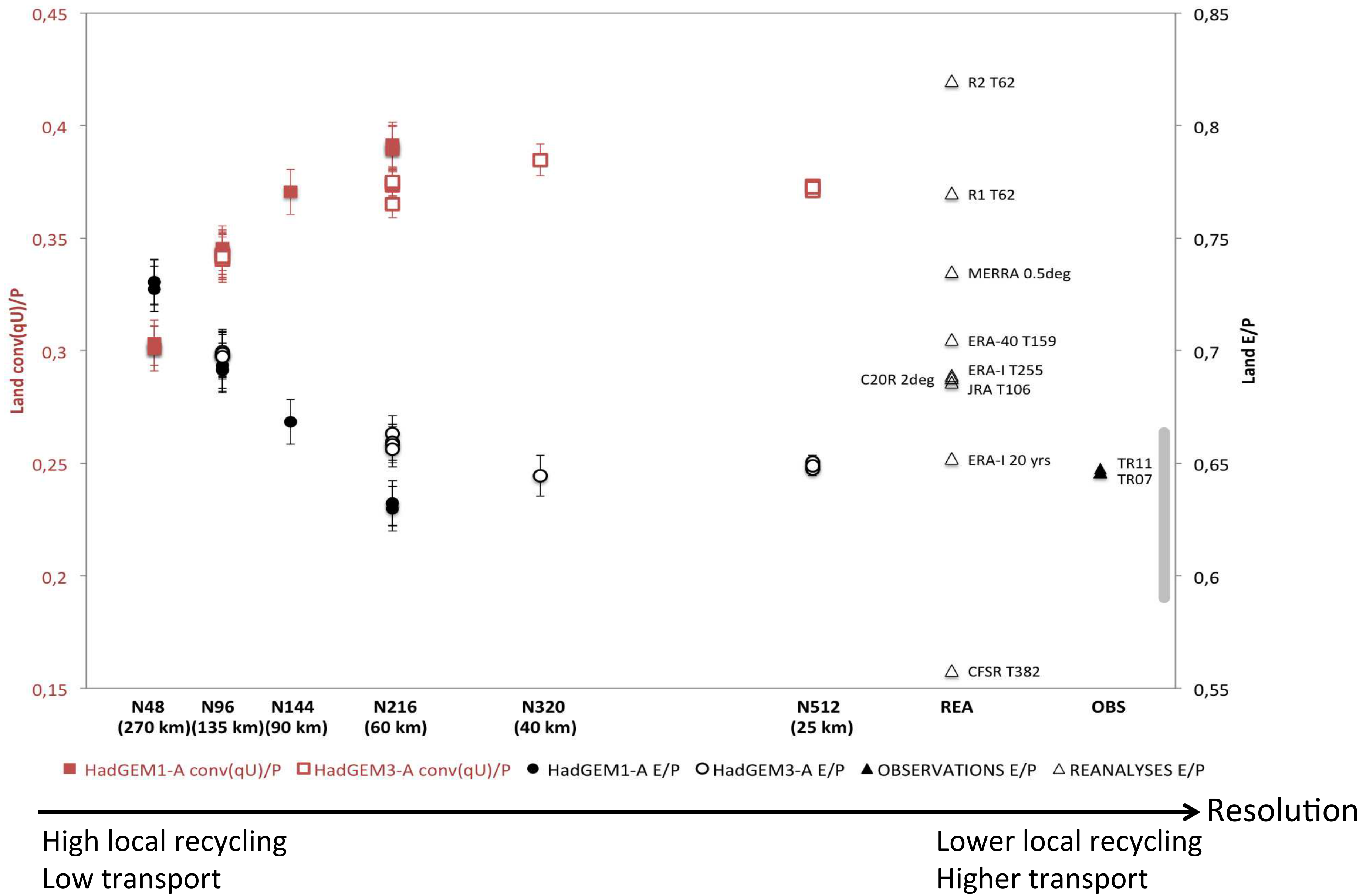


What changes with resolution?
Hopefully, some important things do depend on resolution.
Global hydrological cycle

Demory et al., Clim. Dyn., submitted

Over land



Demory et al, Climate Dynamics, submitted

Knowledge Transfer Partnerships

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UPSCALE: emerging processes and GCM high-fidelity

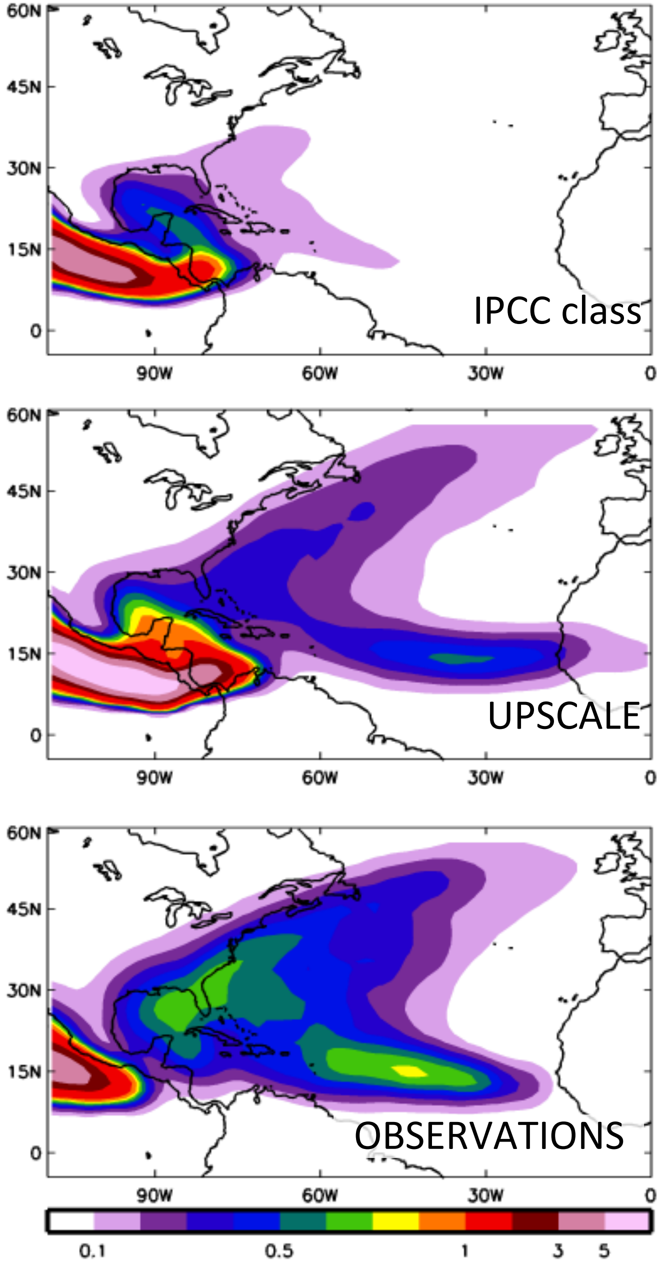
UPSCALE aims to increase the **fidelity** of global climate simulations and our **understanding** of weather and climate risk, by representing fundamental weather and climate processes more completely.

This will enhance our **confidence** in projections of climate change, including extremes such as cyclones, heat waves, floods:

- Extreme events impact society and yet most are **absent** in IPCC-class climate models (see an example in the figure)
- These are rare events and require a large sample to be studied robustly
- UPSCALE uses a fine grid, similar to that used in global weather forecasting, with a set of simulations for both current and future climates

Strachan e et al., J. Clim., 2012 and Vidale et al. 2013, in preparation

Tropical cyclone track density (transits per month)



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PRACE enables Science: Tropical Cyclone Variability

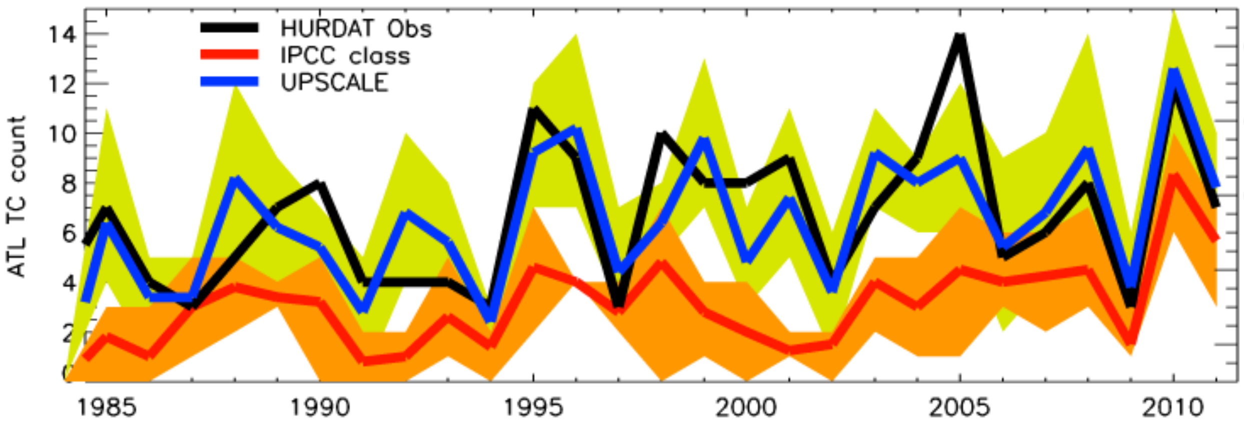
- The UPSCALE higher-resolution models simulate these storms far better than IPCC-class models

IPCC class = N96 5 member ensemble

UPSCALE = N512 5 member ensemble

Correlations: N96=0.61 → N512=0.76

•Number of hurricanes (ensemble mean and range) over the Atlantic for IPCC-class and UPSCALE models, with HURDAT observations



Strachan e et al., J. Clim., 2012 and Vidale et al. 2013, in preparation

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TC correlations (1985-2011) vs HURDAT

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Resolution Basin	N96 (5 member)	N216 (3 member)	N512 (5 member)
Atlantic	0.61, 0.57, 0.5, 0.22, 0.23 (0.61)	0.54, 0.66, 0.44 (0.69)	0.65, 0.66, 0.52, 0.6, 0.63 (0.76)
W Pacific	0.57, 0.52, 0.52, 0.48, 0.45 (0.67)	0.65, 0.49, 0.6 (0.7)	0.42, 0.44, 0.5, 0.45, 0.48 (0.59)
E Pacific	0.51, 0.54, 0.32, 0.5, 0.23 (0.54)	0.47, 0.48, 0.46 (0.54)	0.4, 0.43, 0.51, 0.41, 0.45 (0.5)
Indian	0.01, -0.14, -0.29, -0.14, 0.03 (-0.16)	0.07, 0.0, -0.18 (-0.04)	0.22, -0.37, -0.3, -0.32, -0.18(-0.3)

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Strachan e et al., J. Clim., 2012 and Vidale et al. 2013, in preparation

MSLP-10m wind speed relationship at peak

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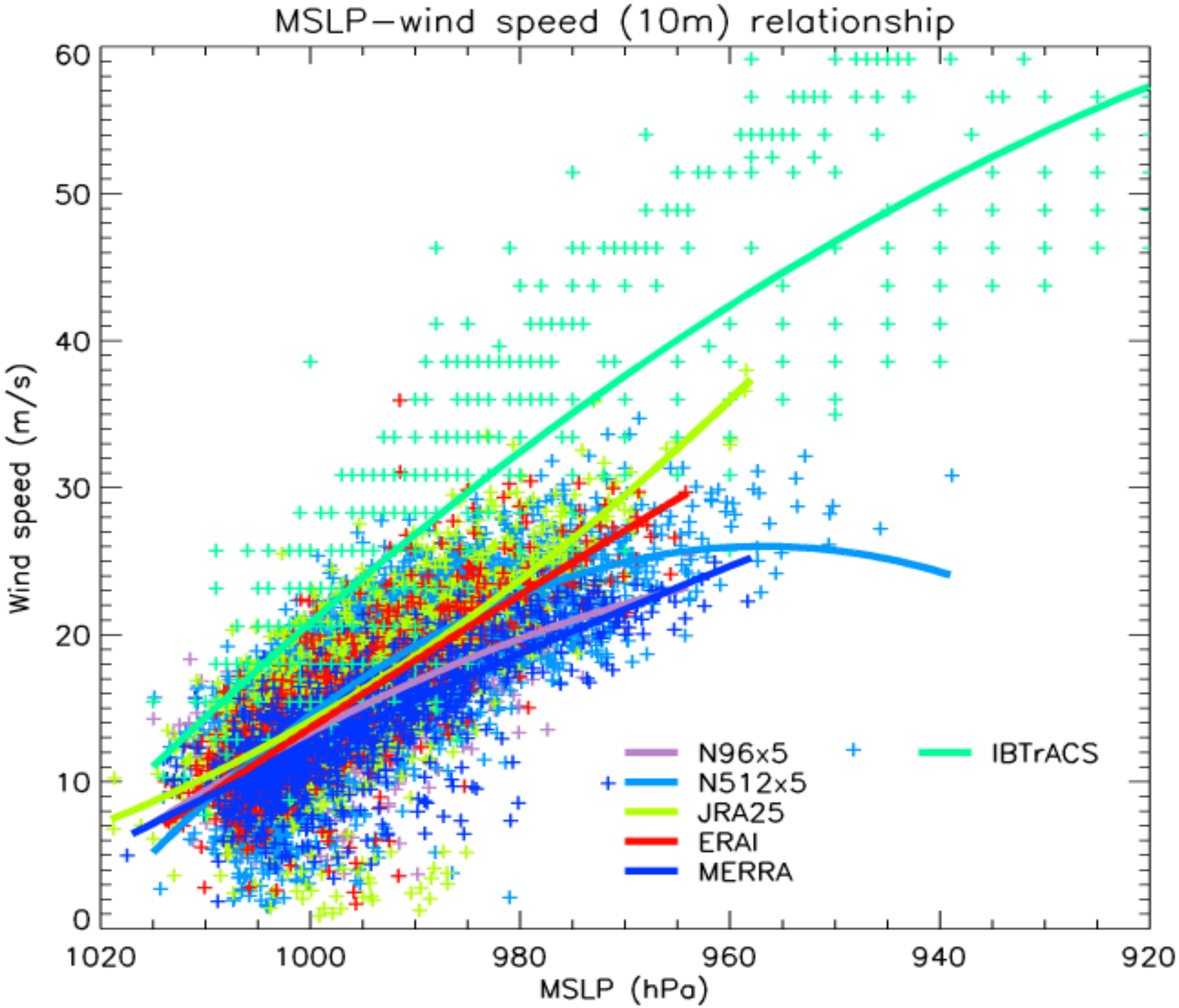
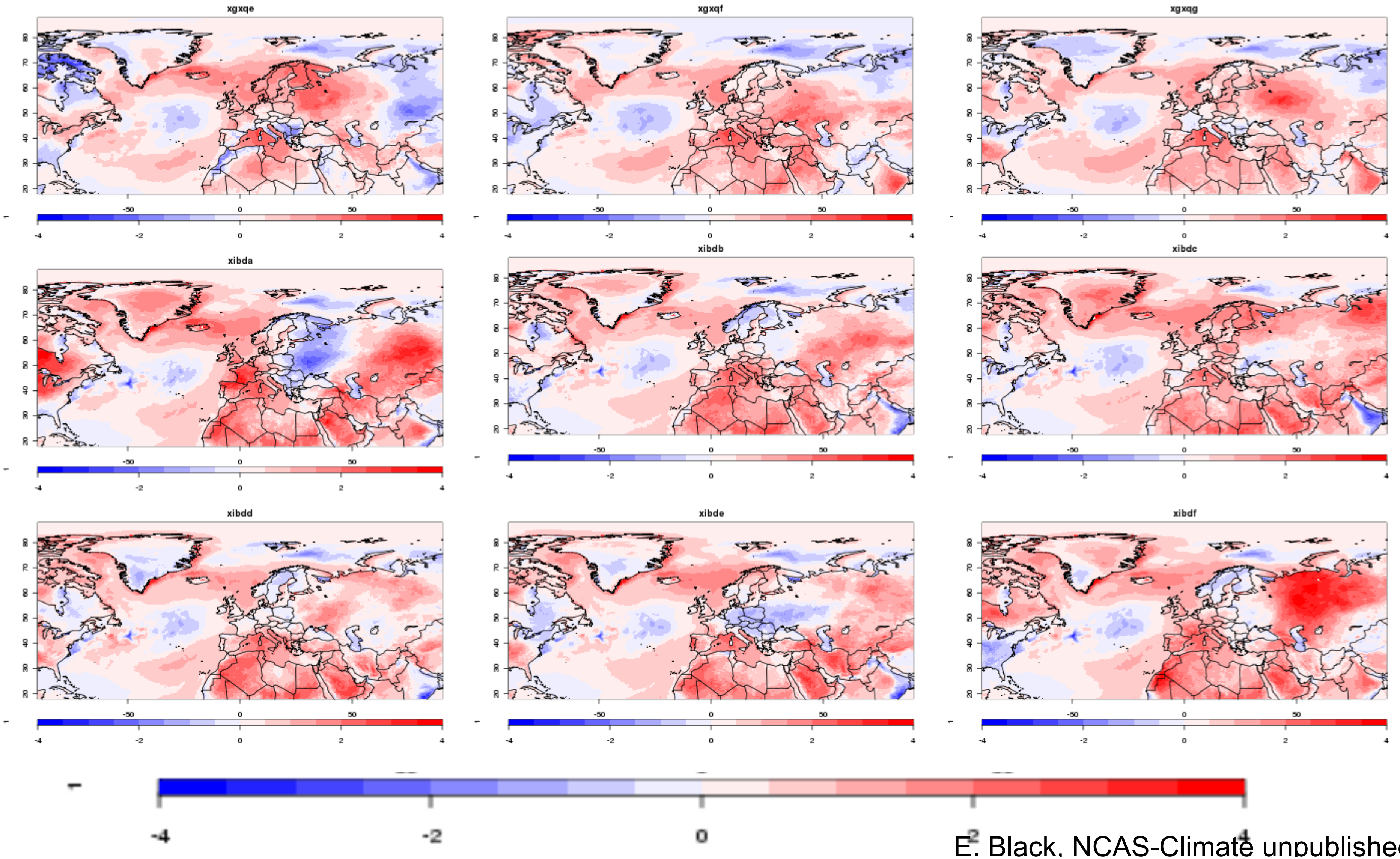


2003 in the n512 simulations: JJA Temperature anomaly

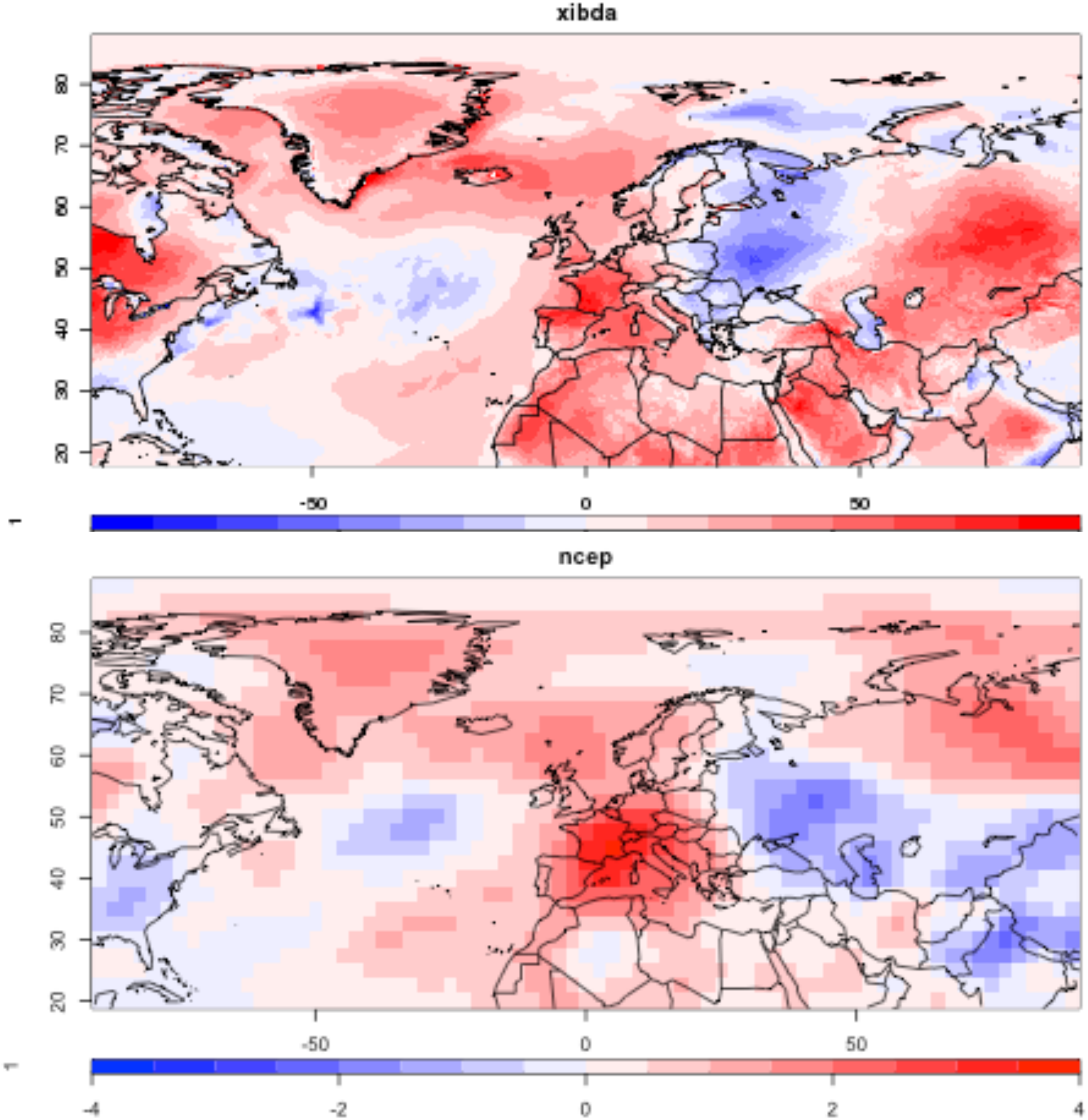


E. Black, NCAS-Climate unpublished

•First place in the beauty contest…

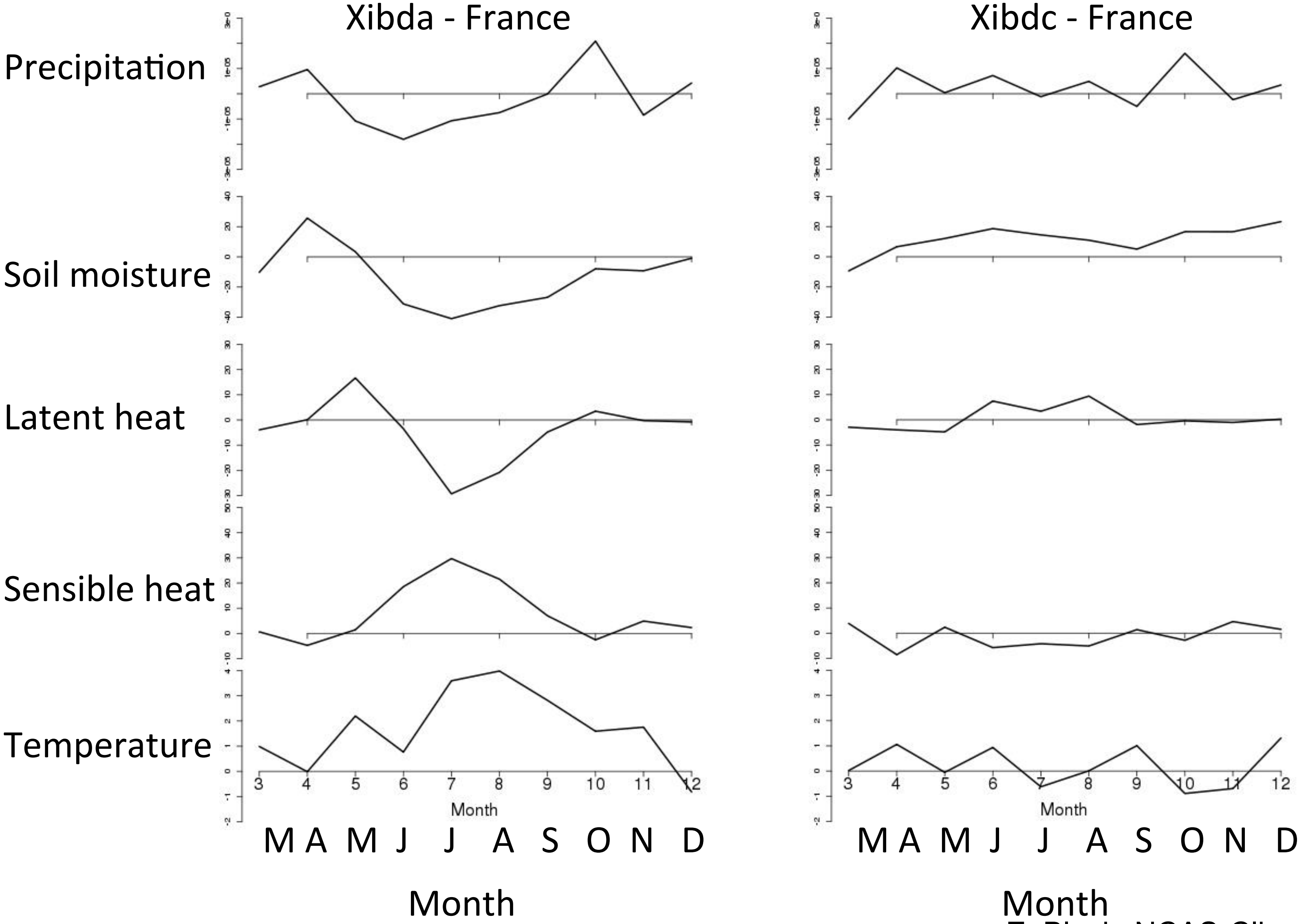
•xibda

•NCEP



E. Black, NCAS-Climate unpublished

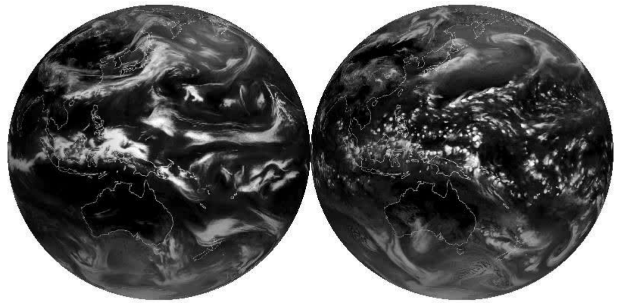
European Heatwave pre-conditioning: Sequence of events

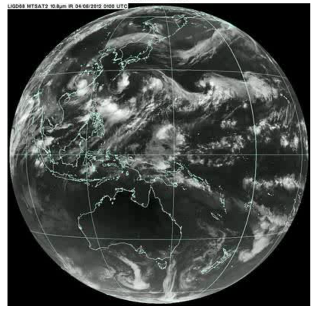


E. Black, NCAS-Climate unpublished

N1024: 12km GCM
developed for PRACE-UPSCALE

- First time that a Global Climate Model leads its NWP "parent" in resolution
  (current MO NWP still at 17km)
  - obvious strategic value to the MO and this received top-priority support by all divisions
- Developed both a **standard HadGAM3 version**, with parameterised convection and an **experimental version with explicit convection.**





(top left) Hourly OLR from global N1024 with parameterised convection

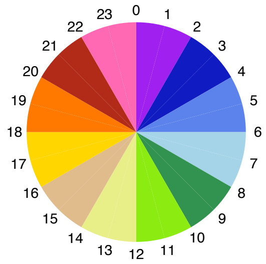
(top right) Hourly OLR from global N1024 with explicit convection (Smagorinsky)

(bottom left) Hourly Infra-Red from MTSAT satellite

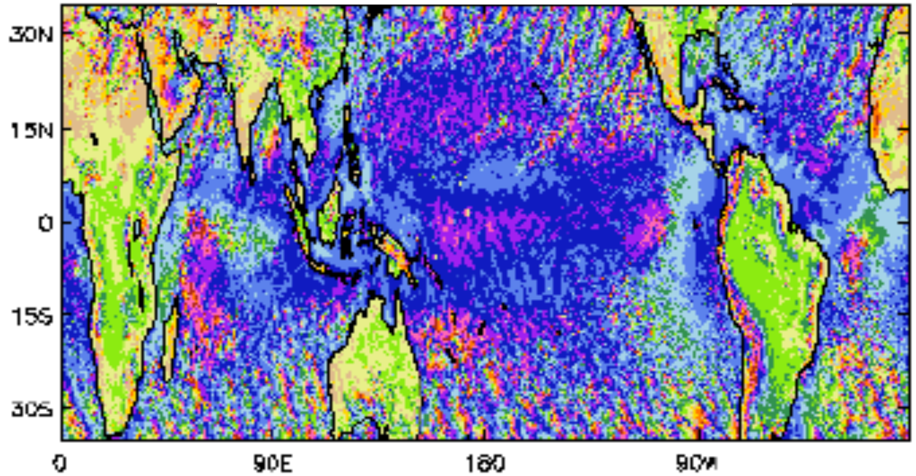
101 caveats of explicit convection at 12km…

- Consider the explicit convection version just as a process study:
  - We don't represent convection at 12km (or even at 1km properly)!
  - But the convective parameterisation has big issues too
  - Probably the lowest resolution for which we can consider switching off the parameterisation, also for stability reasons
  - And mid-latitudes may well be not as good as with parameterisation

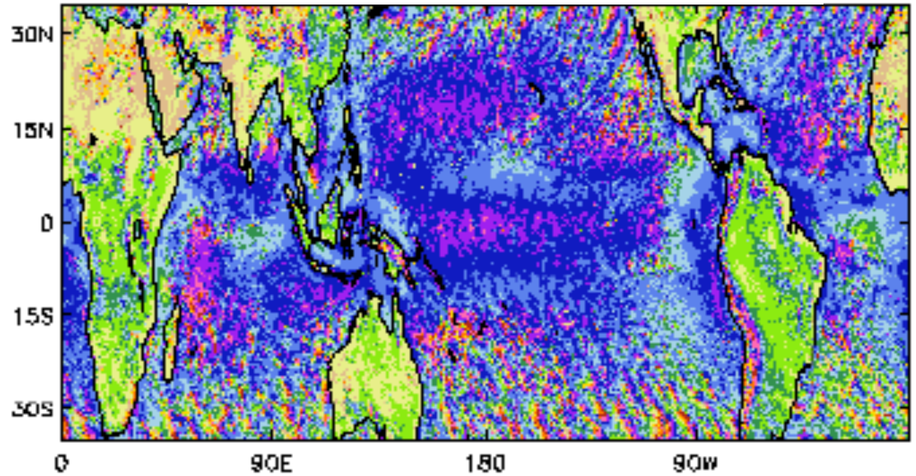
Local time of peak precipitation for 12km models (diurnal cycle) – Mar-Feb 08/09



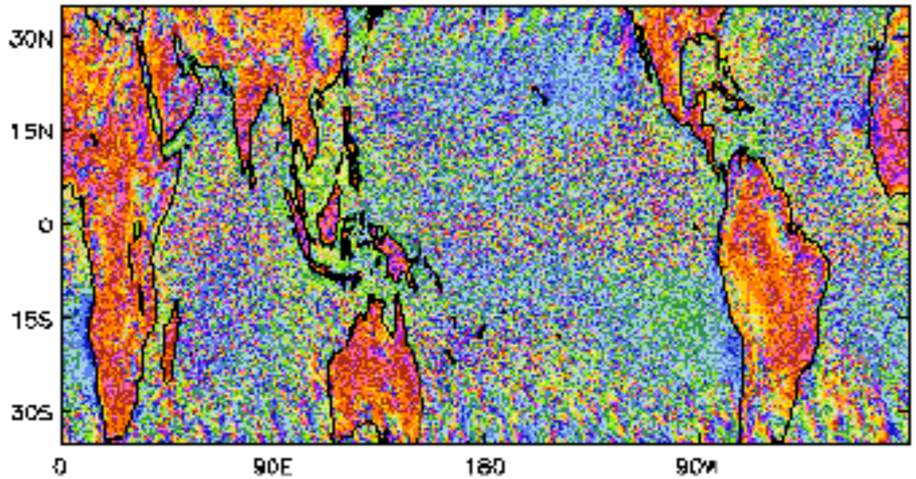
Conv param (GA4)



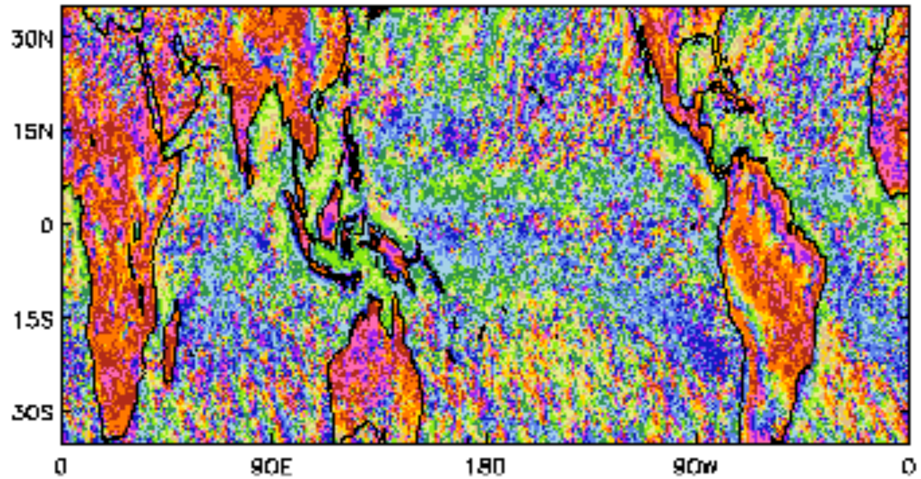
Shallow param

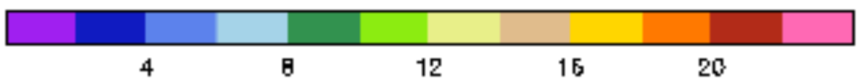


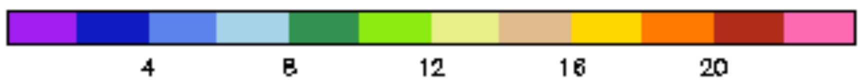
Explicit convection



TRMM observations







Propagating convective systems over Africa

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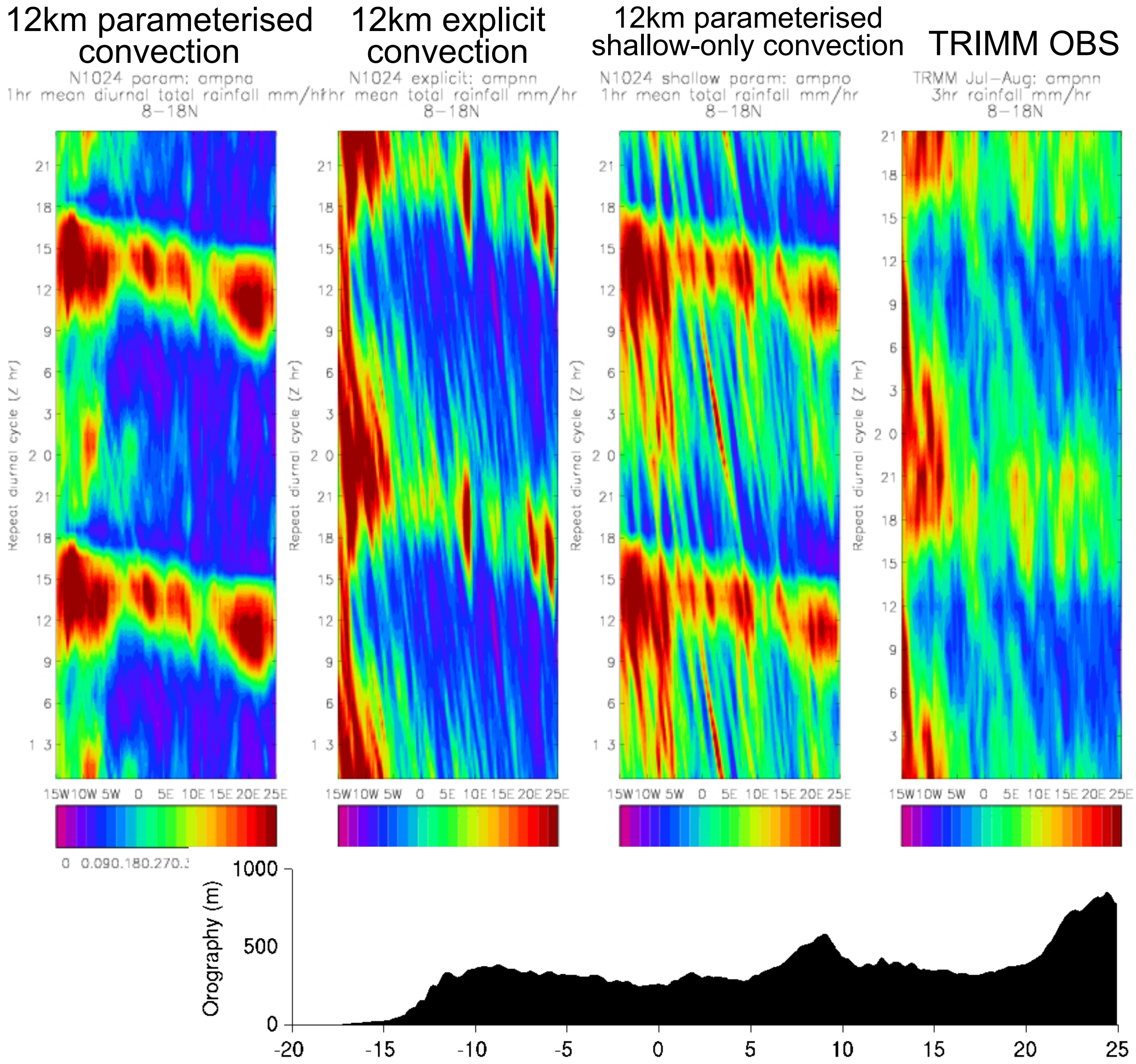

West African Monsoon region – mean diurnal cycle

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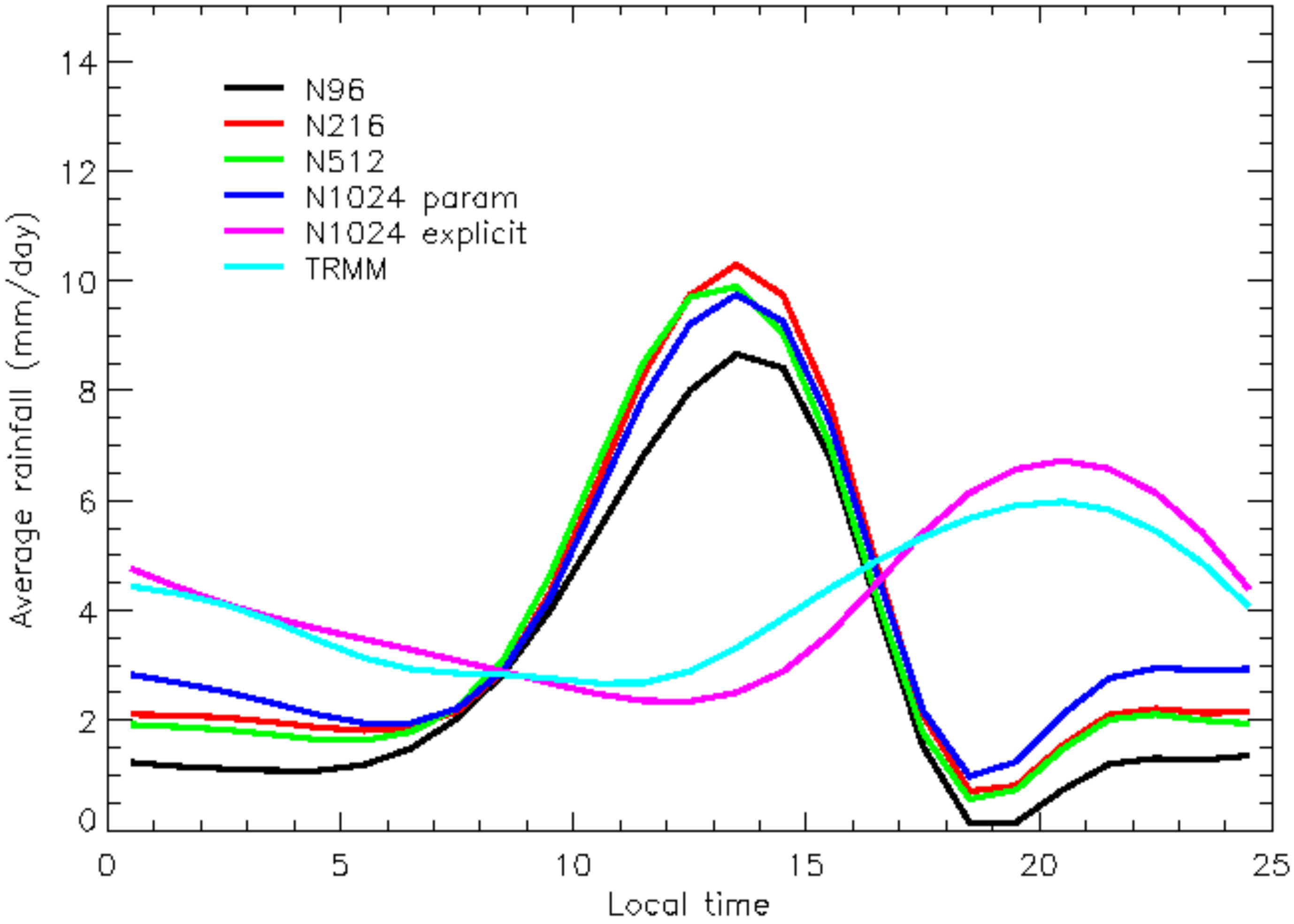

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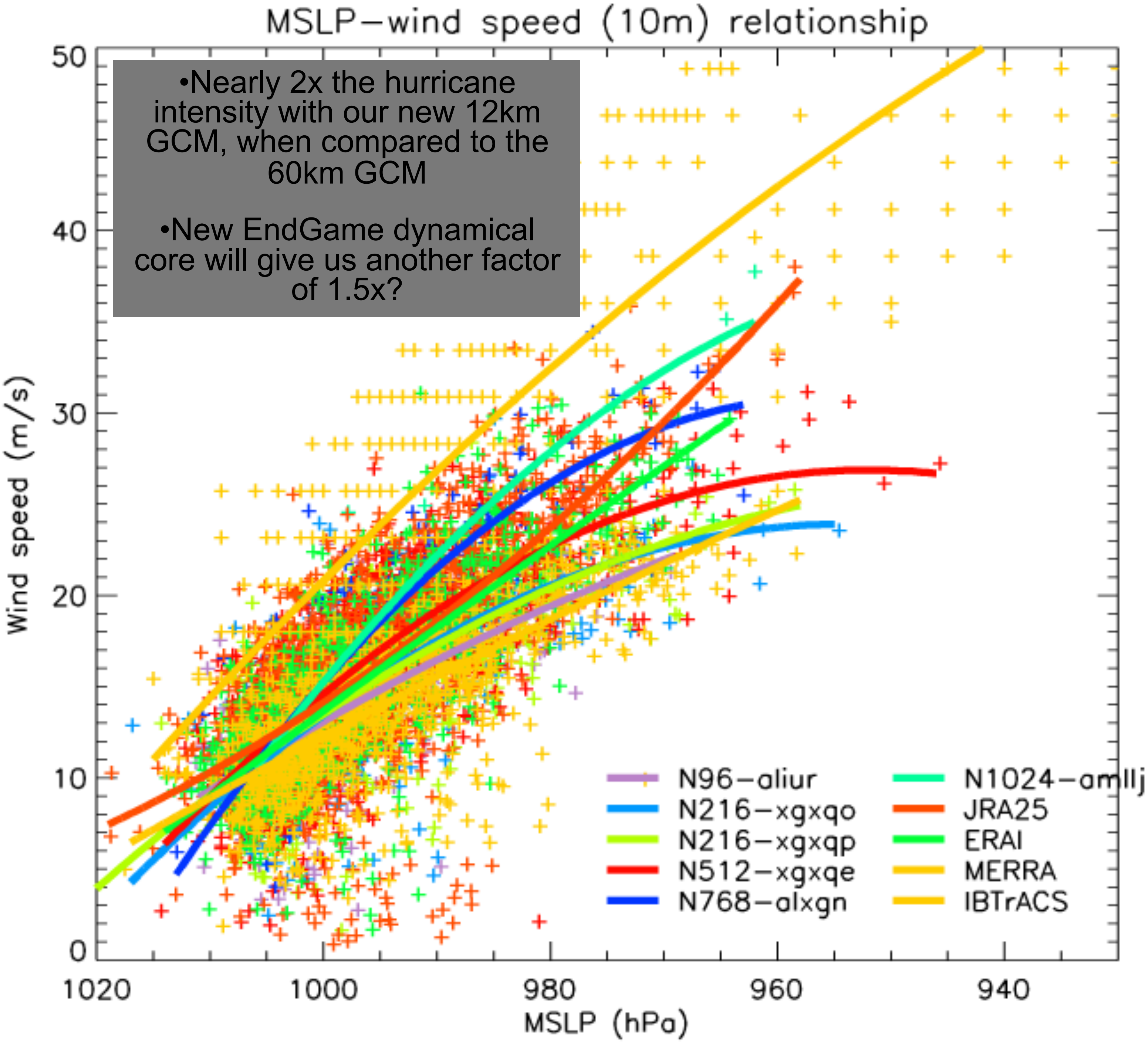
•Nearly 2x the hurricane intensity with our new 12km GCM, when compared to the 60km GCM

•New EndGame dynamical core will give us another factor of 1.5x?



•HadGEM3-A

•GA4

•1 year of 12km (N1024)

•4 years of 17km (N768)

Future plans

Joint Weather and Climate Research Programme

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- Analysis and understanding
  - Work with cloud (and cloud-system) resolving models to understand/ improve parameterisations
  - Coupling to eddy+boundary current resolving ocean model
  - Understanding where models converge, e.g. based on emerging processes
  - Scale interactions:
    - Clouds and climate
    - TCs and their contributions to global energy+water cycles
    - Planetary waves, blocking, feedbacks with land surface anomalies (heatwaves, droughts)
- Applications to study of climate change
  - Model suitable for decadal scenario integrations
  - N512 future timeslice (2100) runs to look at changes in variability, e.g. tropical cyclones
  - SUKV runs forced by global 60km model (present day + future) to look at possible future changes in extreme precipitation
- Future projects
  - Collaboration with UTexas@Austin & JPL
  - 12km global integrations with explicit convection
  - Coupling to the ORCA12 eddy-resolving ocean
  - Welsh Extreme Weather Initiative using SUKV model