Theme 1: Innovation and Frontiers in Modelling

WP3, WP4, WP6

Co-funded by
the European Union

PRIMAVERA

Main Activities

- Develop GCMs so that they can perform coordinated experiments at high-resolution, including incorporating new physical parameterisations;
- Design and carry out core 1950-2050 experiments, and targeted sensitivity experiments, to assess the benefits of increased resolution in the ocean and atmosphere
- Explore the frontiers of climate modelling through experiments at ultra-high resolution and through novel approaches to parameterisation for high-resolution models.
- Explore the relative benefits arising from increased resolution and increased complexity/ process representation.

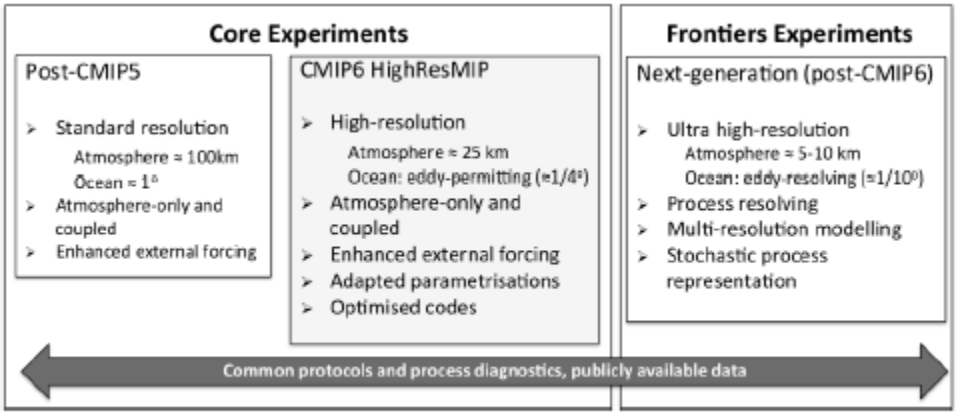
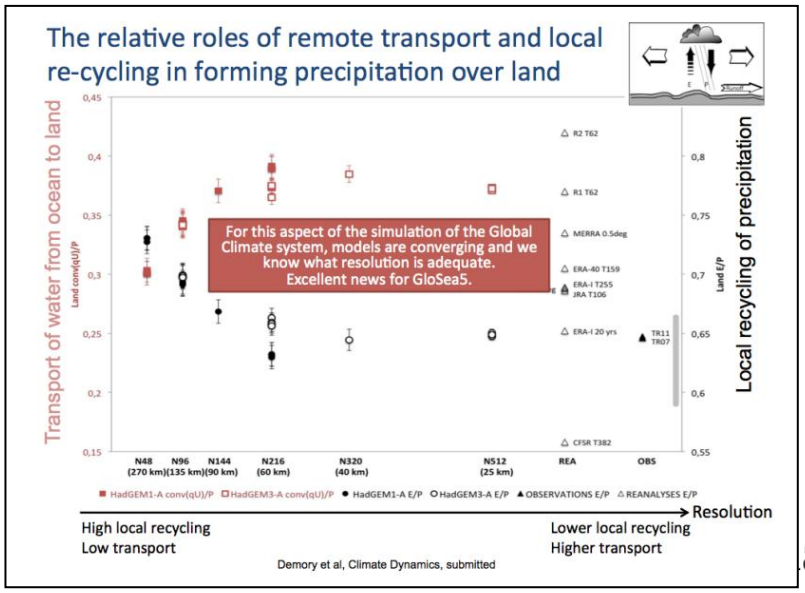
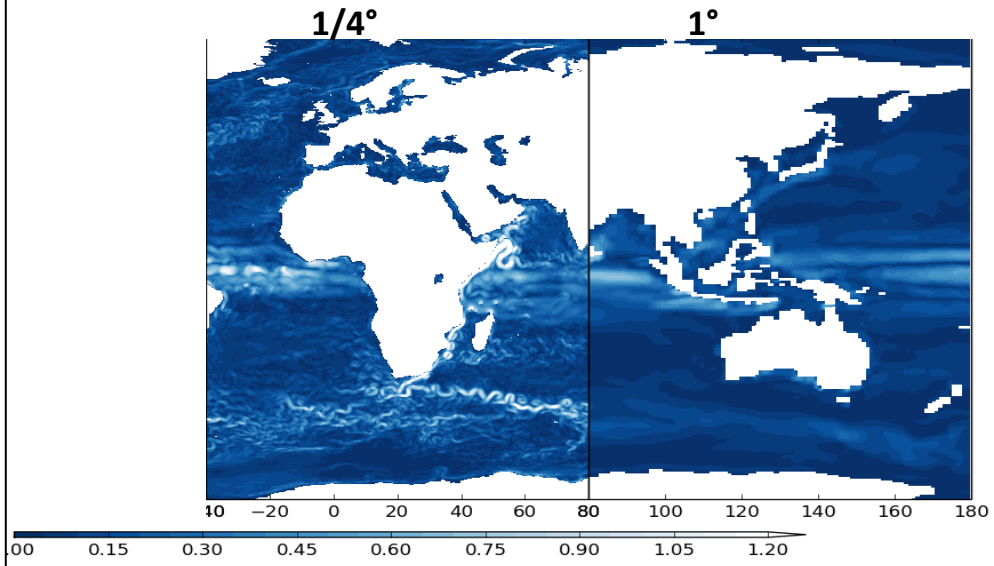


Figure 1.3.3: Schematic diagram of the proposed model simulations to be performed by PRIMAVERA.

Co-funded by
the European Union

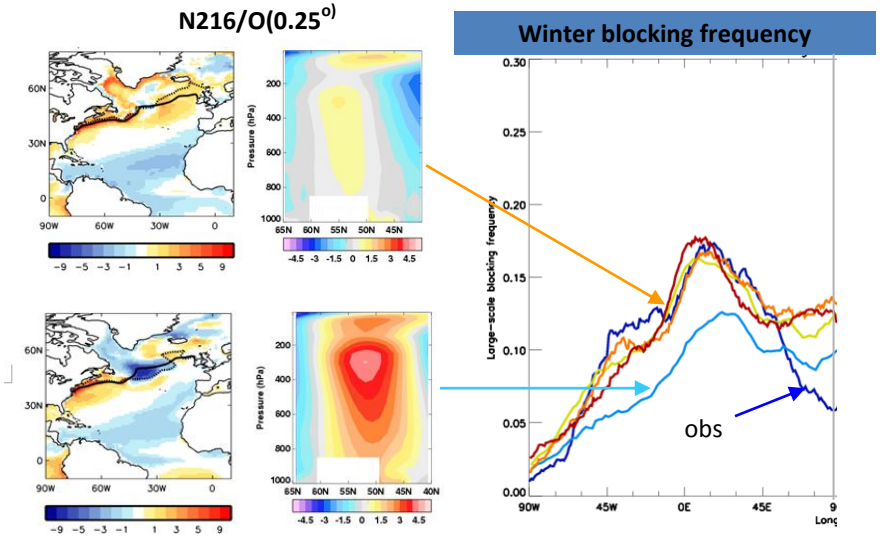
Next Generation models





- A new class of physical coupled atmosphere-ocean-ice-land models is emerging at ~25-50km global atmosphere resolution, ¼ degree ocean resolution

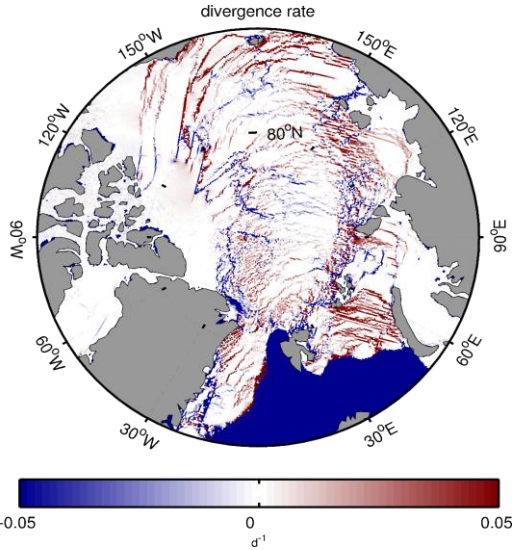
- PRIMAVERA through Theme 1 and co-ordinated experimentation aims to seek to identify robust benefits



Co-funded by the European Union

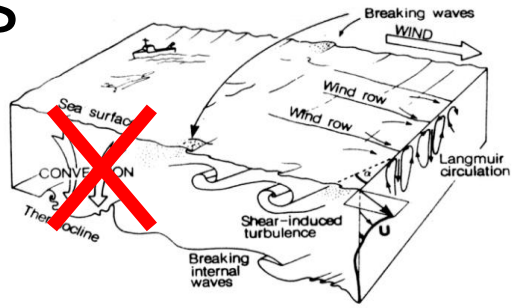
PRIMAVERA

Enabling new physics

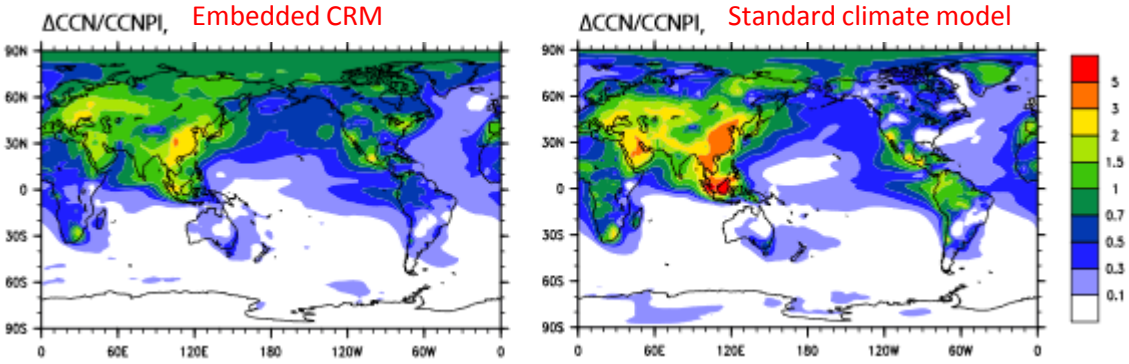


Impact of new **sea-ice rheology**

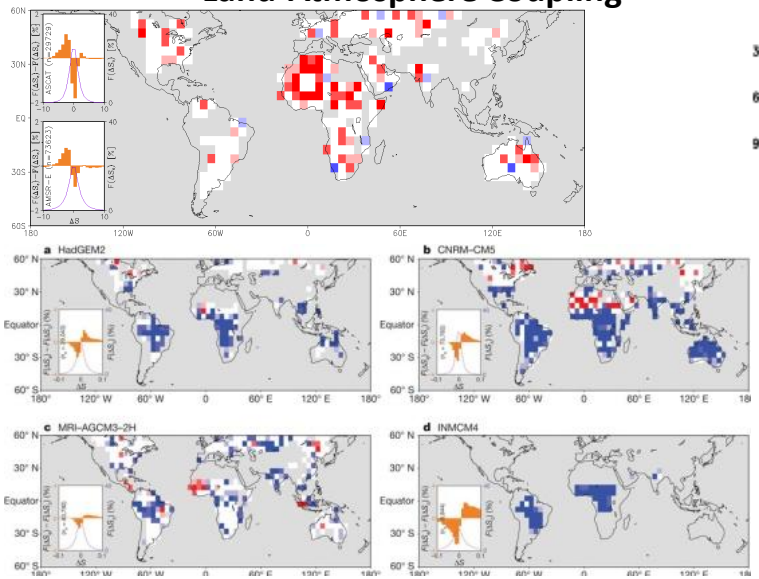
Ocean Mixed-layer processes: Langmuir circulation; sub-mesoscale eddies



Aerosol-Cloud Interactions: Factor increase in CCN over industrial period



Land-Atmosphere Coupling



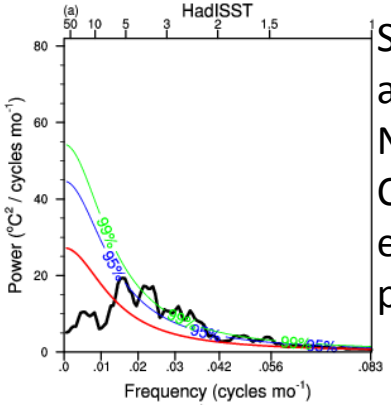
Conventional climate models give <u>opposite</u> signal

- High resolution platform will allow implementation of new physics
- PRIMAVERA through Theme 1 aims to identify benefits, test sensitivity and deliver process understanding

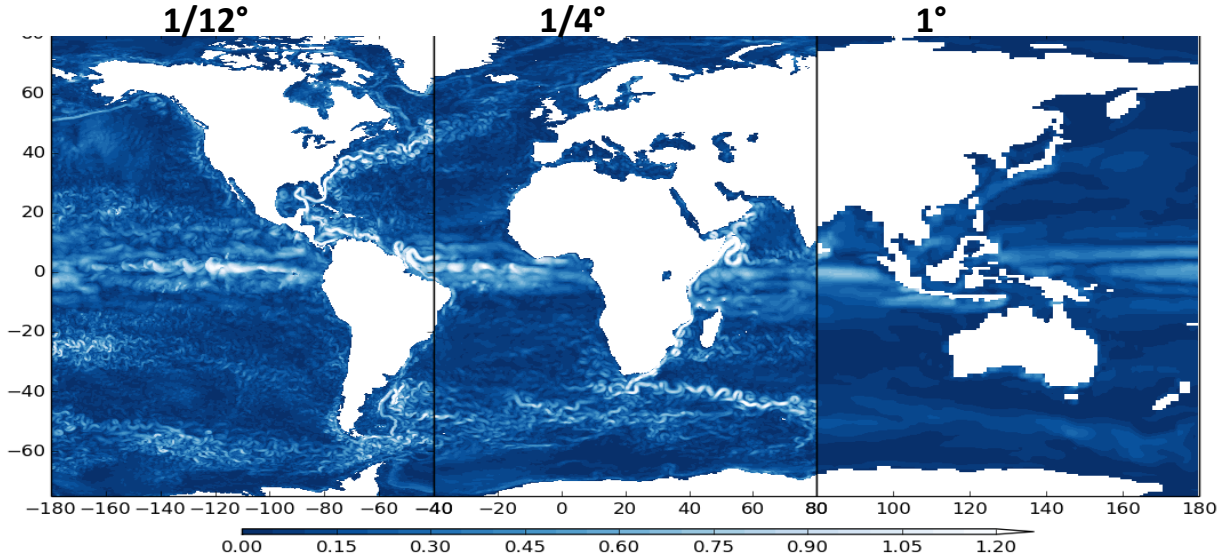
Taylor et al Nature 2012
Taylor et al Geophysical Research Letters 2013

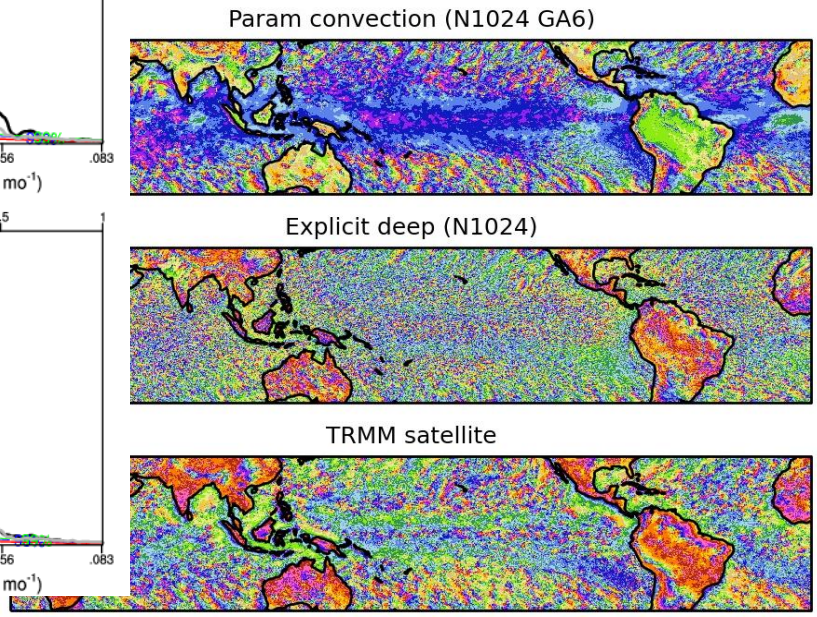
Co-funded by the European Union

Frontiers – Beyond CMIP6



Stochastic and Nino3.4; Christensen et al, in prep





Next step in resolution beyond CMIP6
Questions include:

- appropriate complexity for these resolutions?
- resolution may help to understand uncertainties involved in parameterisations, and hence help e.g. stochastic schemes
- multi-model needed - expensive

ded by
Union

PRIMAVERA

What can we do that is new and exciting?

- Opportunity to understand process representation as an appropriate combination of resolution and complexity
  - How does resolution affect process simulation
  - How should complexity be treated at different resolutions – does it (should it) work appropriately at all resolutions, does it become more crucial at different resolutions?
  - Are there changes in model configuration (“tuning”) that should be different at different resolutions
  - What is an adequate combination of resolution/complexity for addressing particular climate questions?
  - Can we use high resolution simulations to better understand how to parameterize key processes at lower resolution?

Co-funded by
the European Union

WP interactions

- WP1 & 2 are crucial for the success of this theme.
  - Without appropriate process-based metrics, we will be unable to robustly assess our resolution/complexity choices
  - Need to identify the processes important for European climate variability and change

- Potential barriers/traps
  - We are unable to make robust statements about changes due to resolution or complexity
    - Unable to configure the models in a common-enough way, or require too many changes at different resolutions to make work
    - Few ensemble members
    - Short future period
    - New physics only implemented in one model so not able to make robust statements
  - Developments in complexity are difficult and/or expensive to implement at all resolutions
    - Is there a role for shorter simulations, case study-like

Co-funded by
the European Union

WP3: *The role of model physics*

Objectives

- Quantify the need for improved representation or levels of complexity of a range of physical processes within the atmosphere, ocean, land and sea ice in a high resolution environment
- Develop and evaluate the impact of improved representations of key processes influencing European climate

1. What is the added value of complexity in a high-resolution context?

   => Do higher resolutions mean that complexity in representing e.g. aerosol-radiation-cloud interactions becomes critical?

   => Do higher resolutions demand higher complexity?

2. Are there thresholds (such as when convection is resolved) below which key aspects of physics (e.g. land-atmosphere coupling) are not properly represented

3. What can we learn about scale-interactions?

   ⇒ how does land surface react to sub-grid scale distribution of precipitation

4. Within WP3 there will be interactions via the surface radiation budget from new process representation in all model components (Atmosphere, Ocean, Land, Sea-ice)

Co-funded by
the European Union

WP4: *Frontier simulations*

Objectives

- Develop the next generation of coupled models by exploring the concept of 'Beyond simple parameterisation' by testing different approaches to the representation of sub-gridscale processes.
- Assess the relative benefits and costs of each approach, and provide recommendations for future development.

1. Lack of representation of sub-grid scale variability and the uncertainty in model parameters mean that the parameterisation process is a large source of error in climate simulations.
   => Can we use resolutions less "controlled" by parameterisations to better understand this uncertainty?
   => These resolutions may help to understand uncertainties in parameterisation schemes and hence improve e.g. stochastic schemes
   => May also allow implementation of new schemes, such as microphysics, which require explicit convection

2. Do this in different ways
   a. Increase resolution everywhere:
      ⇒ Explicit convection atmosphere simulations at 6-10km, eddy-resolving ocean coupled model
   b. Increase resolution in places thought to be important for European climate:
      ⇒ Unstructured mesh approach, ocean/sea-ice model FESOM
   c. Use stochastic schemes to represent the unresolved sub-gridscale processes, allowing uncertainties in parameter values

3. What can we learn by comparing and contrasting these different approaches?

Co-funded by
the European Union

PRIMAVERA

WP6: *Flagship simulations*

Objectives

- To deliver the core PRIMAVERA flagship simulations at low and high resolution, both coupled and forced AMIP-style, conforming to the HighResMIP experimental design.
- Coordinate the delivery and availability of core model datasets and documentation to all partners with WP9.

Institution	MO NCAS	KNMI IC3 CNR SMHI	CERFACS	MPI	AWI	CMCC	ECMWF
Model	MetUM NEMO	EcEarth NEMO	Arpege NEMO	ECHAM MPION	ECHAM FESOM	CCESM NEMO	IFS NEMO
Atmos. Res.	60-25 km	T255-799	T127-359	T63-255	T63-255	100-25km	T319-799
Ocean Res.	¼ °	¼ °	¼ °	0.4-¼ °	1-¼ ° Spat. Var.	¼ °	¼ °
Nodes	7834	2500	2000	6000		2000	
Model throughput Model years/day	1.1	3.0	5.0	6.5		0.5	
Core hours/model year	1710E+2	200E+2	96E+2	221E+2		960E+2	
Computer	Archer Cary	Cray Beslow	Bull	Bull		Sandy Bridge	
Archer Equivalent CPU cost per 100 yr (M c.h.)	17.09	3.75	1.22	6.19		13.80	
Data archive per 100 yr	155	39	85	225		91	

Co-funded by
the European Union

Deliverables and Milestones (to Month 24)

D6.1: Model configurations for Stream 1 integrations (Month 4) – WP6
MS 16: Stream 1 runs started (Month 6) – WP6
MS 9: Requirements for completion of frontier integrations and how they might contribute to HighResMIP (Month 6) – WP4&6
MS 10: Readiness of all modelling approaches (eddy-resolving and unstructured mesh, stochastic and atmospheric convection-permitting) assessed, in order to start planned long simulations (Month 12) – WP4
MS 6: Plan and tools for co-ordinated process-based analysis of the core-simulations. (Month 12) – WP1&2
D6.2 : Stream 1 historical AMIP runs (Month 12) – WP6
D6.3 : Stream 1 future AMIP runs (Month 14) – WP6
D2.1 : Assessment of benefits of increased ocean resolution (Month 15) – WP 2
D6.4 : Stream 1 control and historic coupled runs (Month 18) – WP6
D3.1: Quantification of aerosol-radiation-cloud interactions (Month 24) – WP3
MS7: Deliver recommendations and model configurations with improved physics for Stream 2 of the core integrations (Month 24) – WP3
D2.2: Quantification of benefits of increased atmosphere resolution (Month 24) – WP 2

Co-funded by
the European Union