Future Climate Modeling and Scenario activities at the Rossby Centre

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With input from Rossby Centre Staff

Areas of emphasis over the next few years

Global and Regional Earth System Modeling

Reliable estimates of long-term climate change require the inclusion of all possible feedback processes in climate models. This requires inclusion of a suite of new biogeochemical processes **e.g. interactive Carbon cycle, including all sources and sinks**

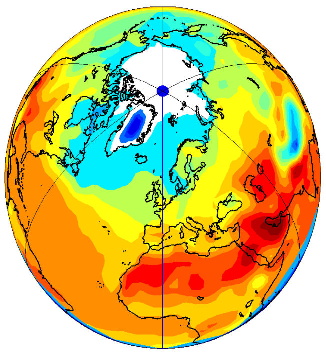
Climate Prediction

How does it differ from climate scenarios? Can it offer better information on the evolution of the **total** climate system (**natural and human forced changes**) on shorter timescales (1-40 years)

Higher Regional Model resolution

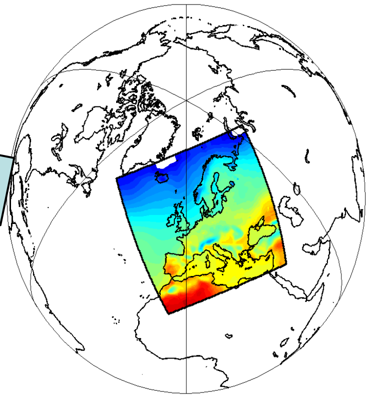
Downscaling of global climate simulations is required to bring such information to the spatial scale of use in impact & adaptation work.

High resolution offers more detail & better simulated processes.



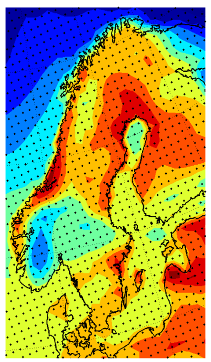
GLOBAL MODELS

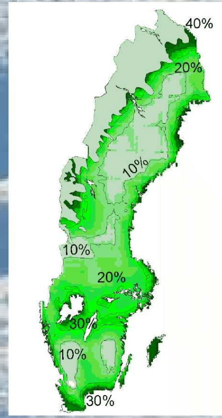
HadCM3, ECHAM5, **EC-EARTH**, ECMWF, NCEP

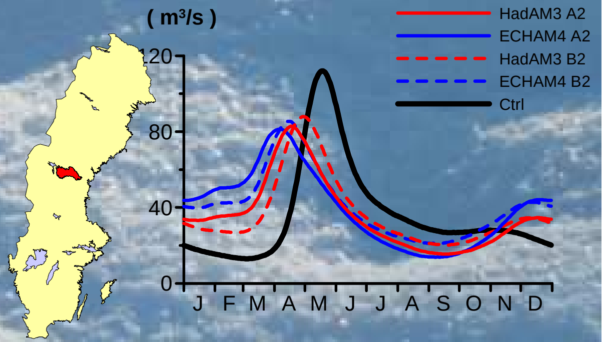


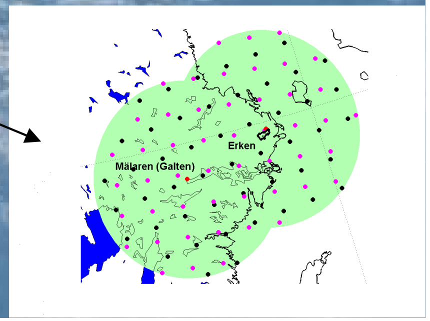
REGIONAL MODELS

RCA, RCO, HBV, HYPE, **RCAO**









Impact Studies

Hydrology, lakes, ecosystems Forest response, glaciers, ...

The Rossby Centre Ensemble

Different AOGCMs

Different initial conditions

Different model formulation (GCM)

Different emission scenarios

Different horizontal resolution

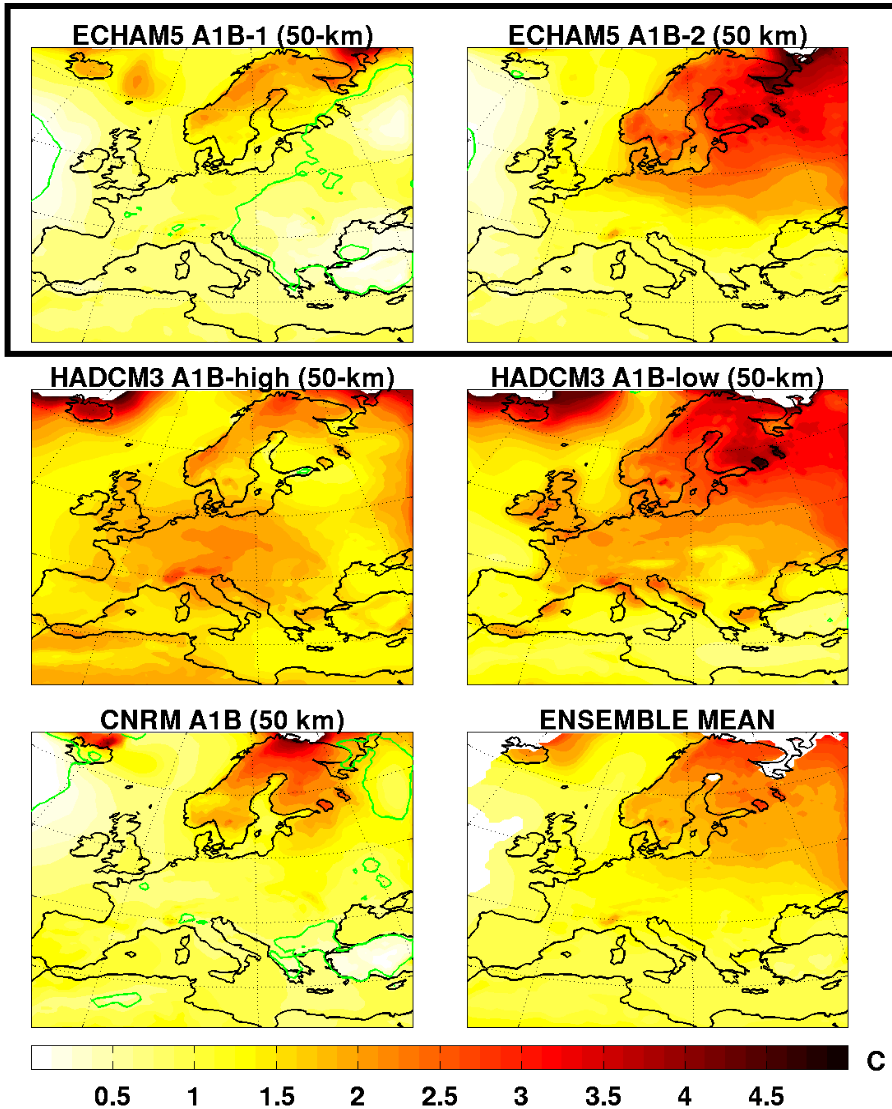
All simulations on the ENSEMBLES grid with RCA3

No	AOGCM **(Institute, country)**		Emission scenario	Horisontal resolution **(km)**
1	**Arpège (CNRM, France)**		**A1B**	**50**
2	**BCM (NERSC, Norway)**		**A1B**	**50**
3				**25**
4	**CCSM3 (NCAR, USA)**		**A2**	**50**
5			**A1B**	**50**
6			**B2**	**50**
7	**ECHAM4 (MPI-met, Germany)**		**A2**	**50**
8			**B2**	**50**
9	**ECHAM5 (MPI-met, Germany)**		***A2***	**50**
10			**A1B**	**50**
11				**50**
12				**50**
13				**25**
14				***12.5***
15			**B1**	**50**
16	**HadCM3 (Hadley Centre, UK)**	**ref (Q0)**	**A1B**	**50**
17		**low (Q3)**		**50**
18		**high (Q16)**		**50**
19		**low (Q3)**		**25**
20	***IPSL-CM4 (IPSL, France)***		***A1B***	***50***

30 year mean winter season temperature change 2030–1975

Quite large differences between the simulated climate change signal.

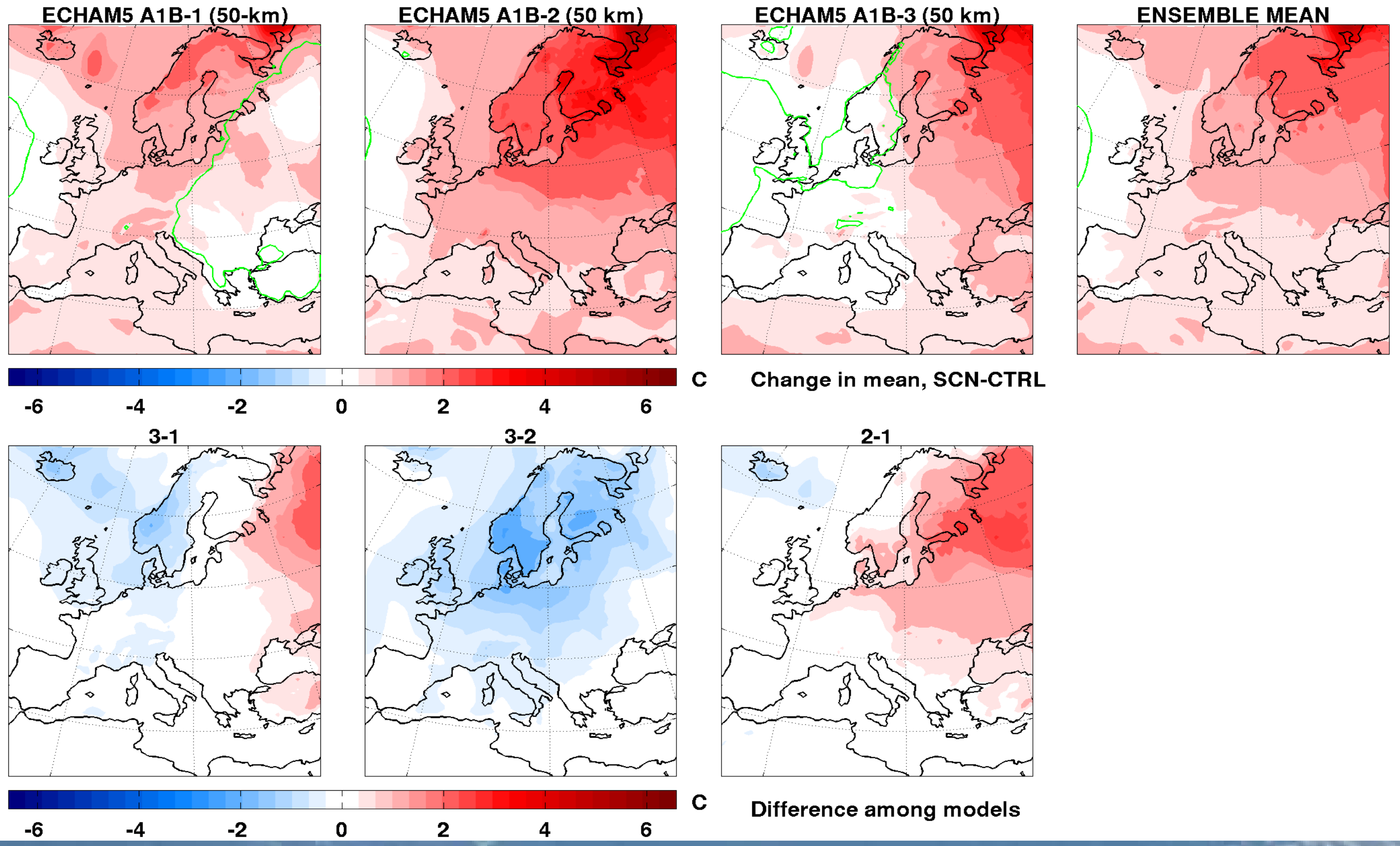
Even between 3 members of the same GCM with same emission scenario (ECHAM5 A1B) but different initial conditions in 1860.



On Shorter timescales climate scenarios suffer from a signal to noise problem. Natural variability is as large as the anthropogenic climate change signal.

30 year mean winter temperature change from 3 RCA runs forced by 3 members of ECHAM5 A1B GCM : 2030-1975

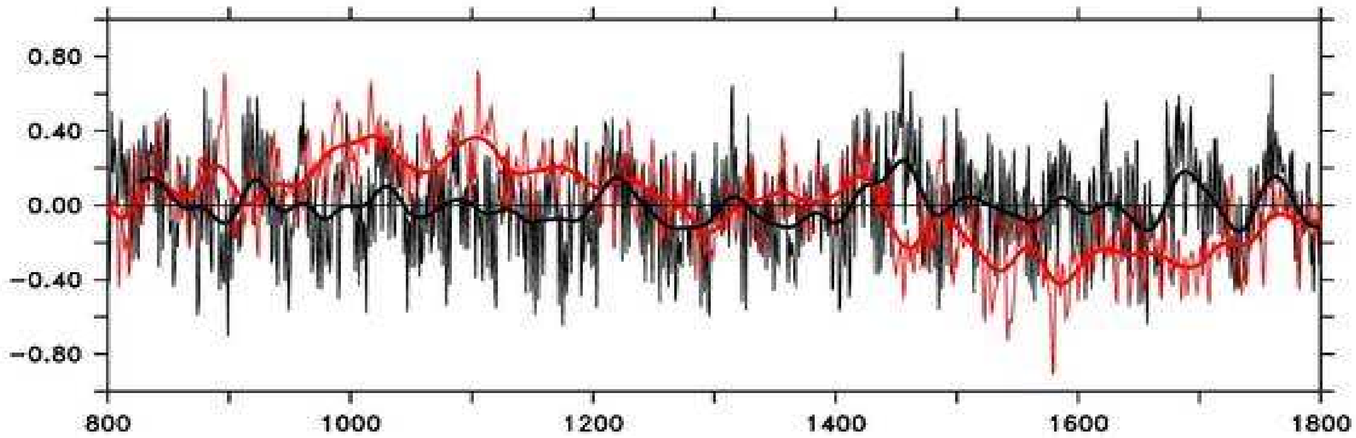
Differences due to using different initial conditions can be of the same magnitude as the simulated climate change signal.



Why is this so?

When we make global climate simulations we first 'spin-up' the coupled system over thousands of simulated years forced only by: The Sun, Earth's rotation and pre-industrial concentrations of greenhouse gases. This is to get the deep ocean circulation in balance

Northern Hemisphere temperature anomalies : COSMOS Millenium Experiment



Reconstructed 'observed' values

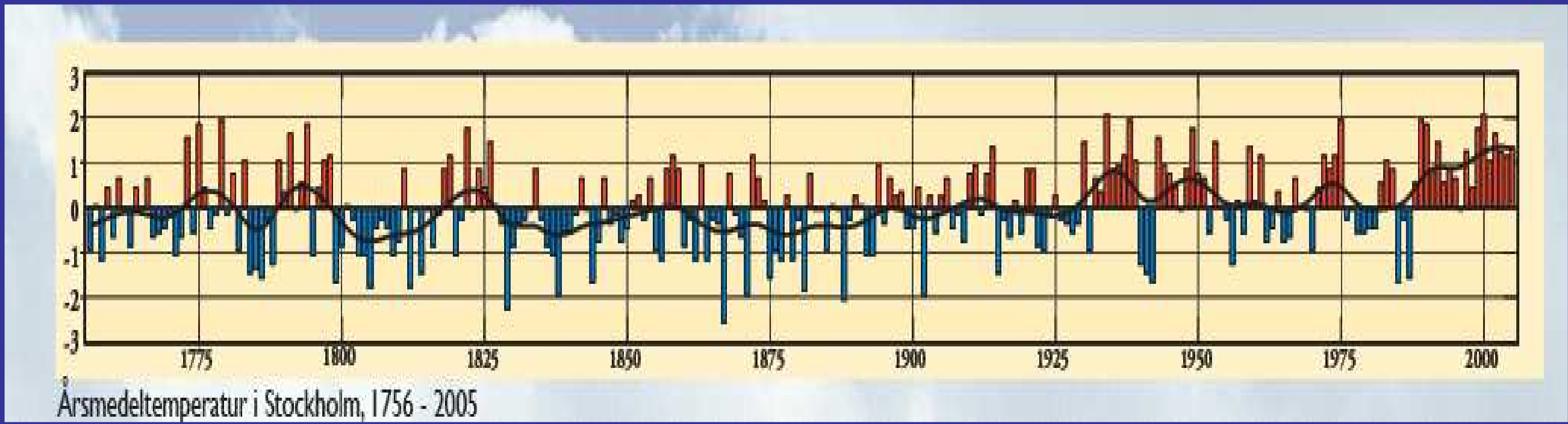
GCM simulated value

Johan Jungclaus MPI

Climate models can simulate a realistic amount of natural variability. But there is no reason to expect this variability is occuring at the same time as it is in reality. **i.e The model calendar is largely imaginary**

In terms of **natural variability** we have no way of knowing where we are in relation to observed variability when we start a model simulation, say in the year 1860 or 2005. **To sample this uncertainty we select a set of initial conditions that encompass the range of natural variability**

Observed Annual Mean Temperature Stockholm 1750-2005



Any greenhouse gas induced trend is likely/hopefully included

A more accurate prediction of the climate evolution over the short term might arise if we could initialize the slowly varying components (ocean, sea-ice, soil moisture etc) with observations

Decadal predictability and climate prediction

The predictability we are familiar with arises from an estimate of future changes in greenhouse gas concentrations, and the climate system response to those changes.

Predictability might also arise from information contained in the initial state of the system

- "committed warming"
- evolution of natural variability of the system

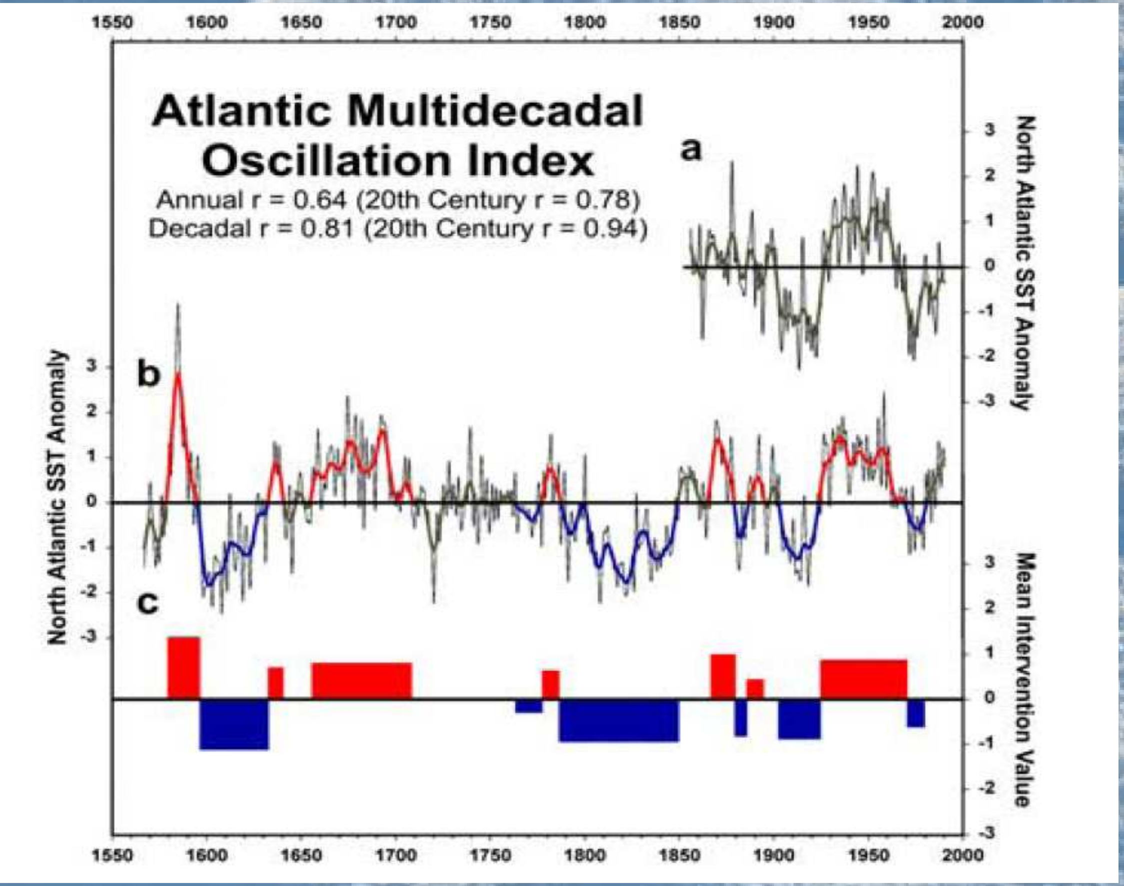
Assuming we can (i) observe this (ii) assimilate the information into our models, (iii) the variability has a predictable component and (iv) our models are good enough to simulate the subsequent evolution of the climate system

We may be able to make some useful statements regarding the evolution of the climate system on a 1-30 year timescale.

Climate Prediction as a mixed initial/boundary value problem

The Atlantic Meridional Oscillation index

A 10-yr moving average of annual North Atlantic SST anomalies

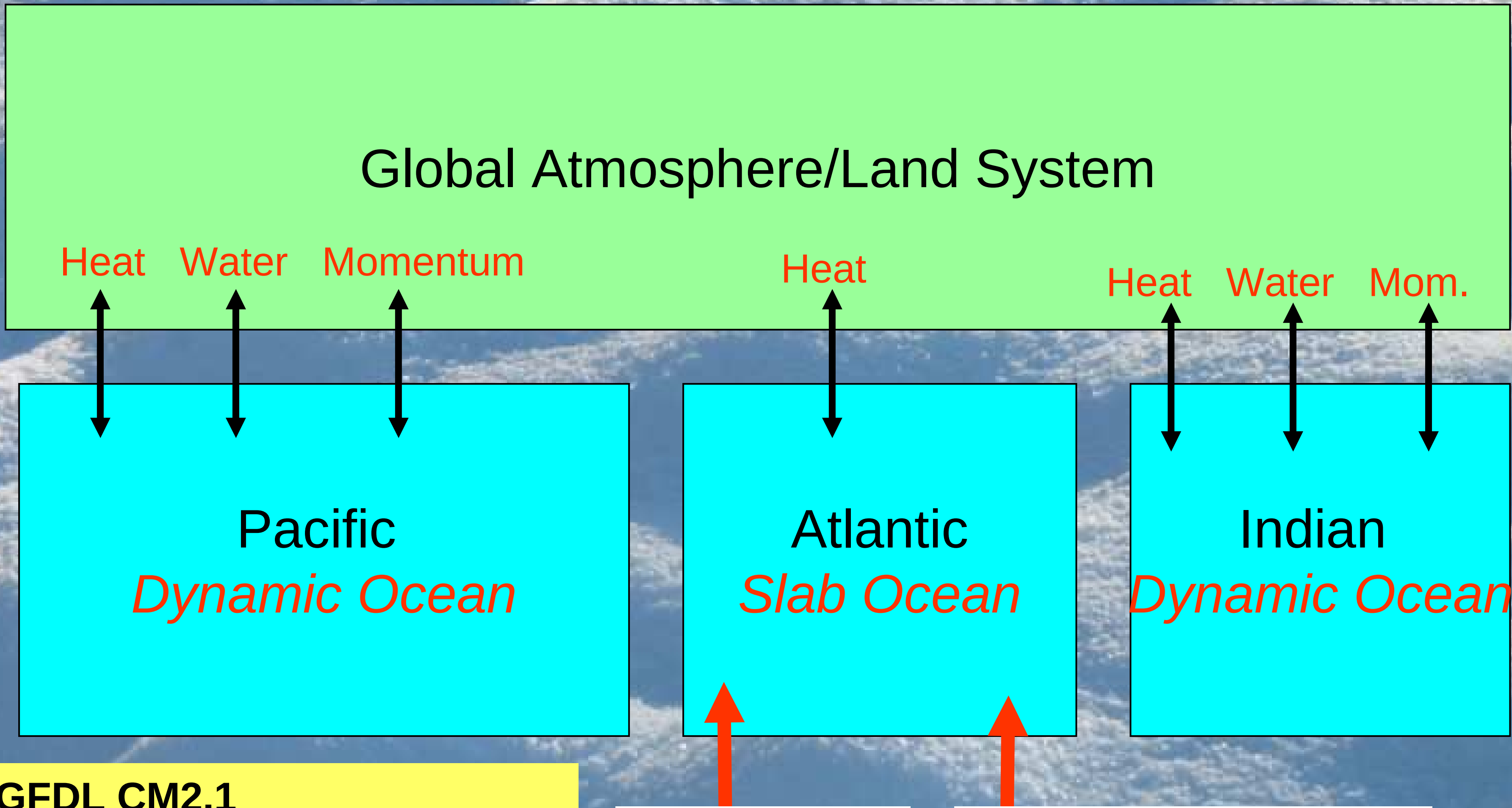


Linked to variability in the Atlantic Meridional Overturning Circulation

S.Gray et al. 2004

A Modeling Example of potential decadal predictability

A Hybrid coupled model - based on GFDL CM2.1 (Delworth et al.)



GFDL CM2.1

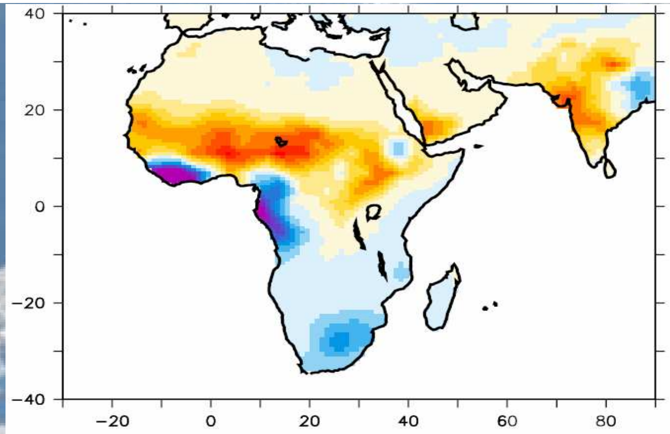
2^o atm

1/3 to 1^o ocn

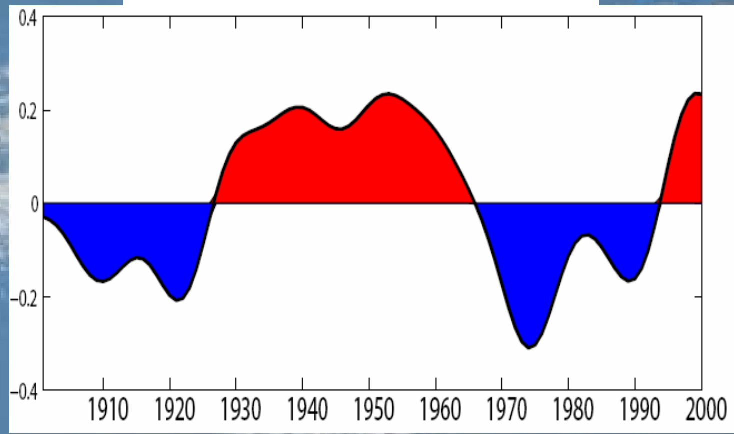
nomads.gfdl.noaa.gov/CM2.X

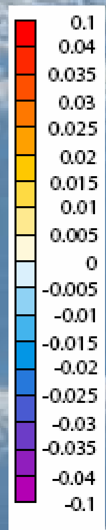
AMO decadal variability appears to project onto Sahel and India summer rainfall variability. Given a reasonable AMO the GFDL model appears capable of simulating this teleconnective variability

Regression of modeled LF JJAS rainfall anomaly on modeled AMO Index

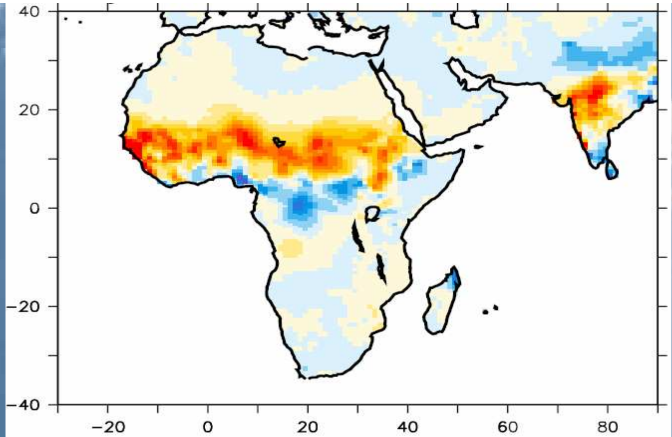


Modeled AMO Index

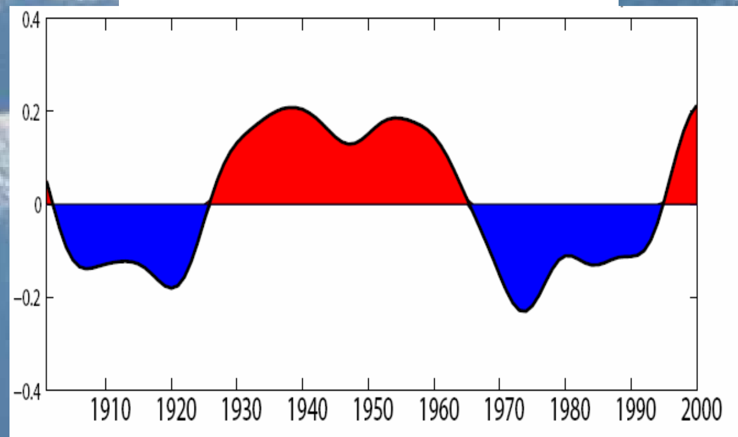




Regression of observed (CRU) LF JJAS rainfall anomaly on observed AMO Index



Observed AMO Index



EC EARTH

A consortium of 7 European Meteorological Services and ~20+ universities developing a common Global Earth System Model

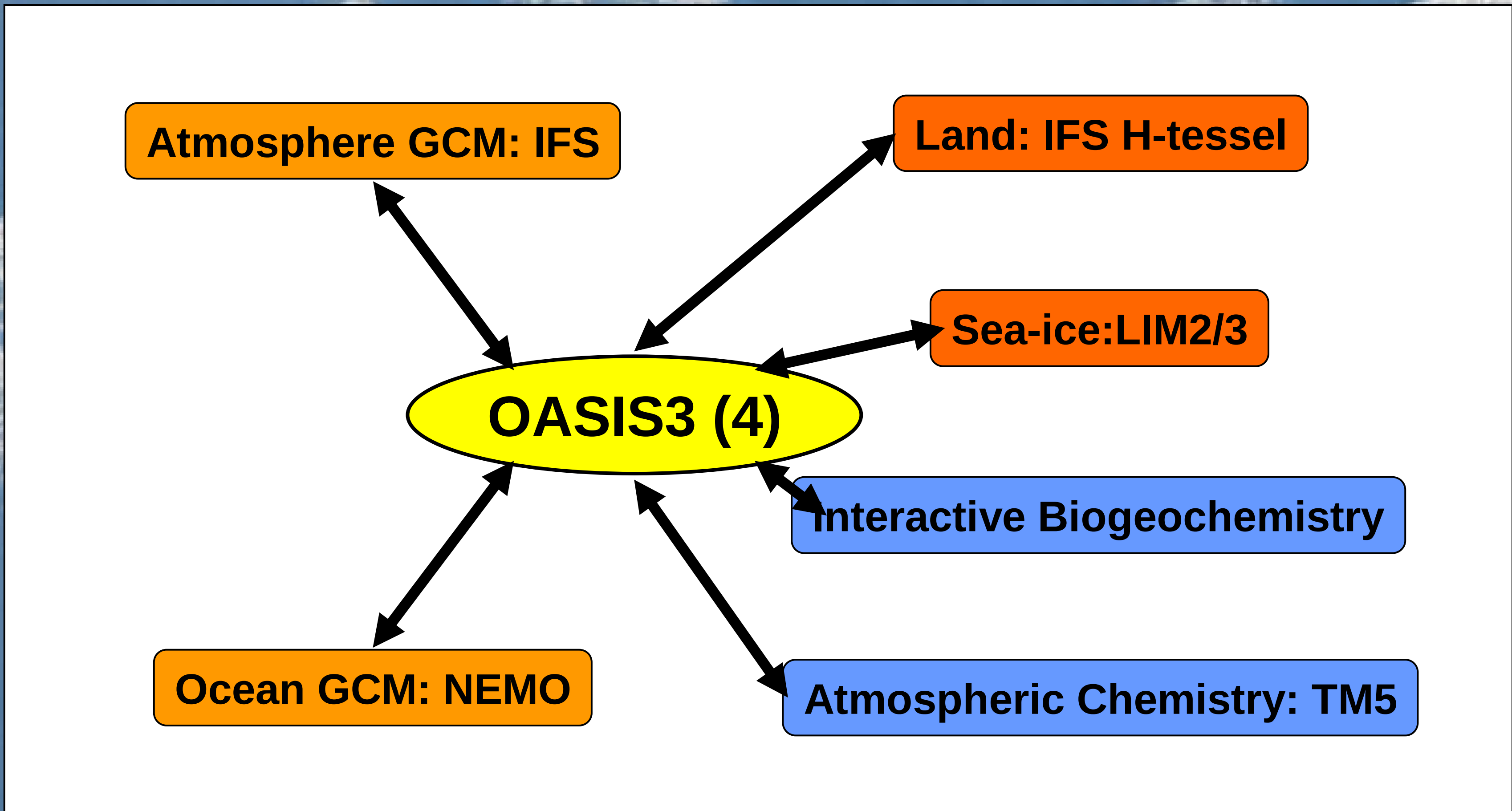
Rationale:

Use the ECMWF coupled Seasonal Prediction System for decadal and centennial timescale climate prediction

ECMWF modeling tools are owned by all European Met Agencies

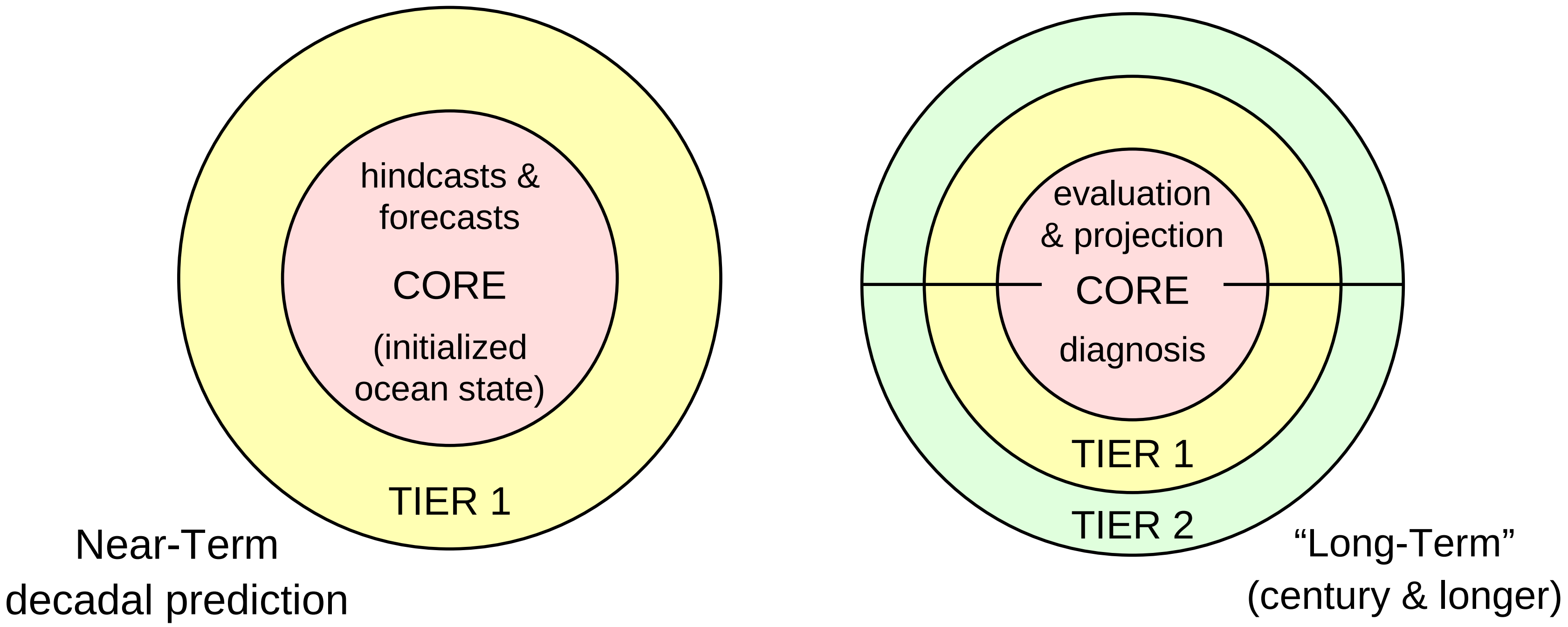
EC-EARTH is being developed both for
Global Climate Prediction and as an Earth System Model

Development is shared across consortium members



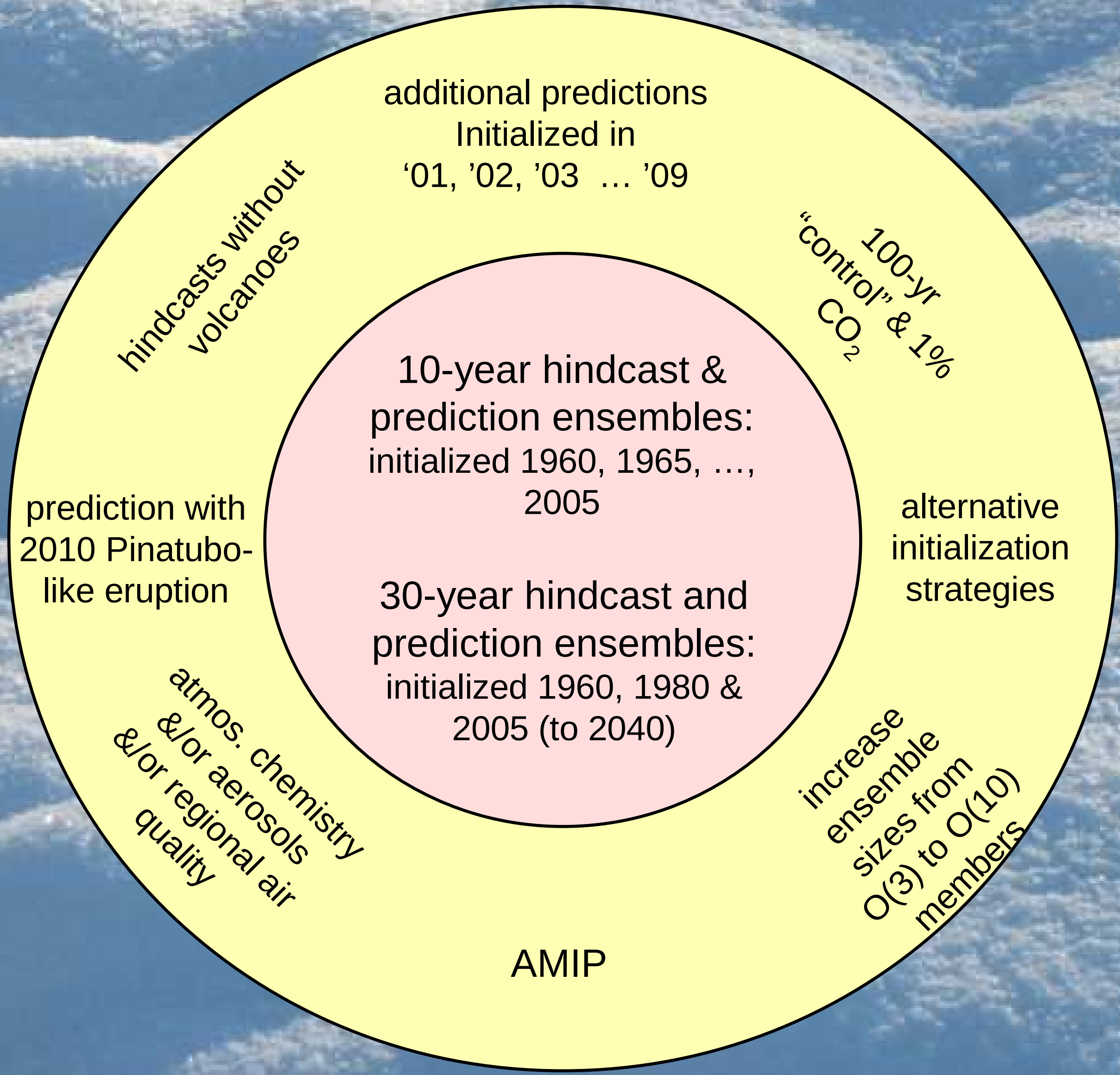
The EC-Earth consortium will make a coordinated set of Global Climate Scenarios and Decadal Predictions as part of the 5th Coupled Model Intercomparison project: CMIP5

The Rossby Centre will be part of this coordinated effort



CMIP5 is the main modeling support for the IPCC AR5

CMIP5 Decadal Prediction Experiments



EC-Earth Global Climate Scenarios (1860-2100) within the CMIP5 project will be made in 2010 and early 2011

We plan to use these simulations in regional downscaling activities at the Rossby Centre in late 2010 and 2011.

EC-Earth climate predictions will be made for CMIP5 during 2010 and 2011 and tested as boundary condition data for regional downscaling in 2011-2012.

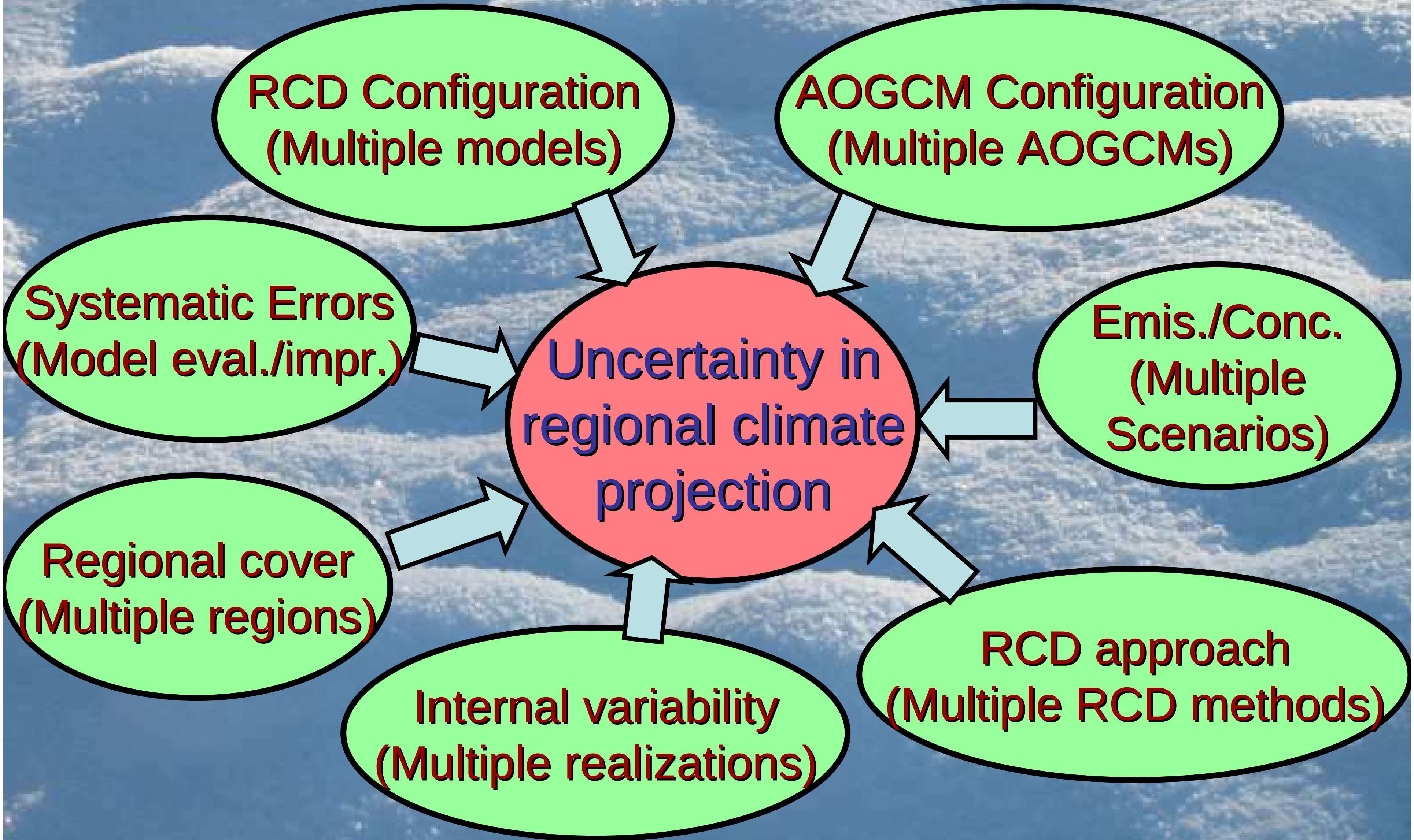
Other CMIP5 GCM results will also be used as boundary conditions for an international regional downscaling project

Coordinated Regional Downscaling Experiment : CORDEX

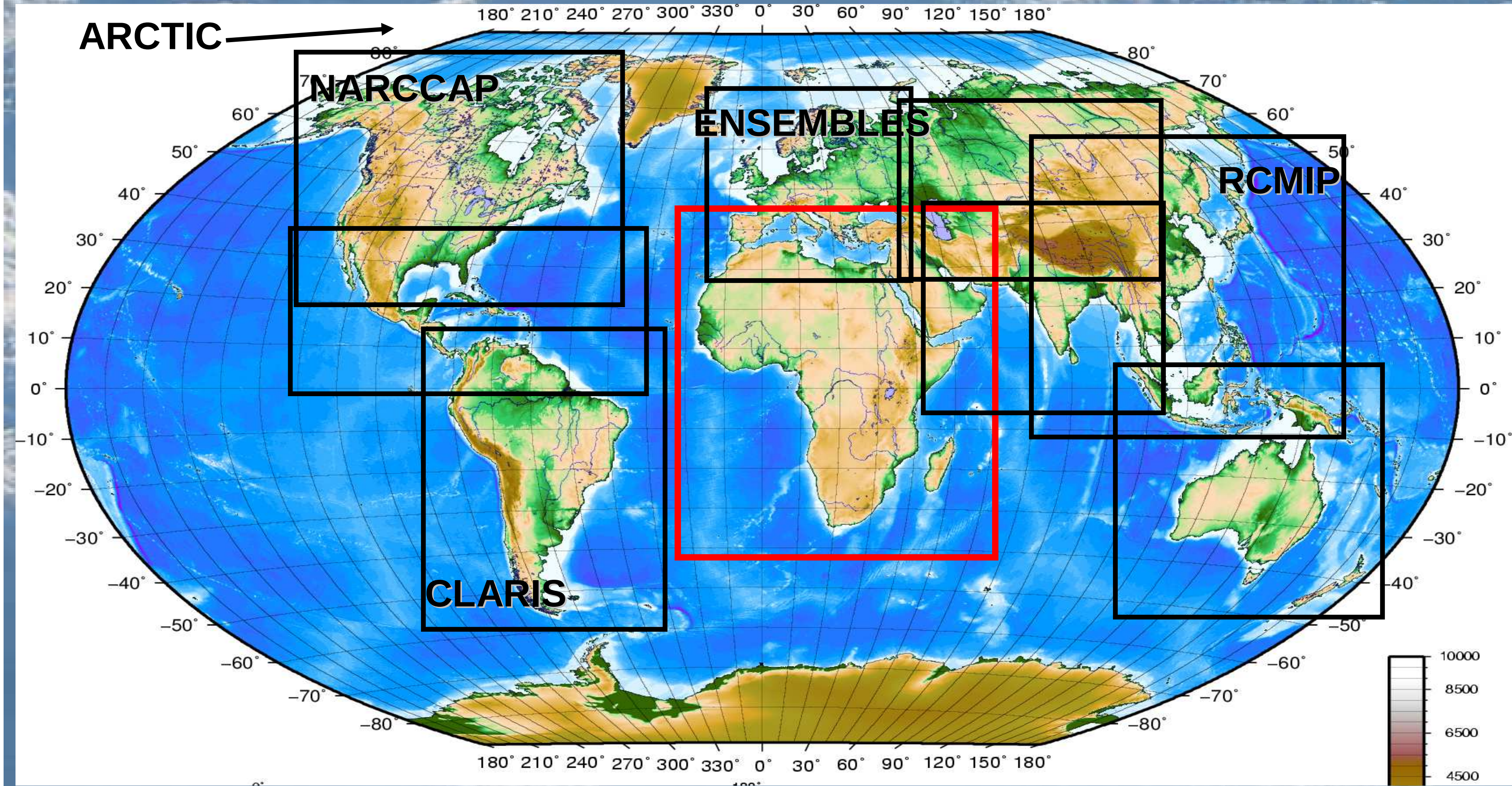
Will develop a matrix of GCM-RCM climate scenarios for the majority of populated regions of the world.

A World Climate Research Program Initiative : CORDEX

To sample the sources of uncertainty in Regional Climate projections to provide more robust data for impact and adaptation work



CORDEX domains

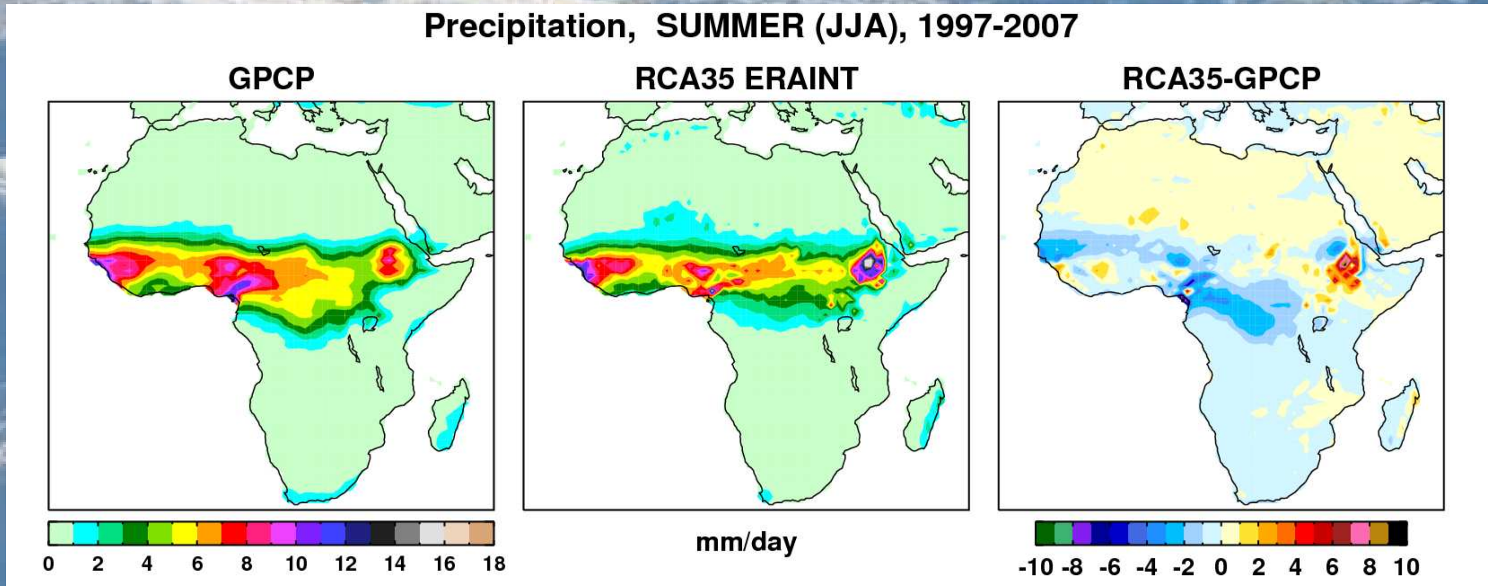


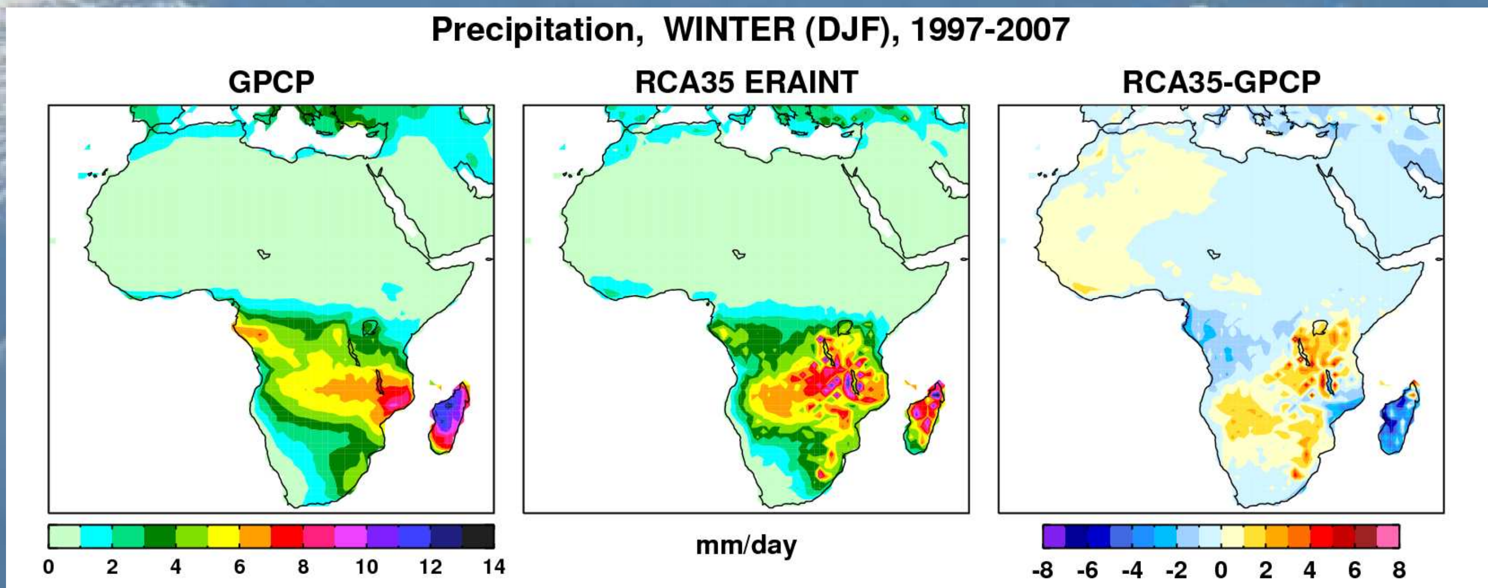
Specific aims and plans for CORDEX

Develop a matrix of RCM simulations that employ:

1. Multiple GCMs as boundary conditions (BCs)
2. Multiple ensemble members of a given GCM as BCs
3. Multiple RCMs driven by a given GCM over a given domain
4. More than 1 representative greenhouse emission scenario
5. Multiple RCM domains across the world
6. With common RCM domains and resolution for each region
7. With common RCM output variables and frequency
8. In a common format
9. Store the results online for subsequent access and use
10. International coordination will focus on Africa 2010-2012

Seasonal Mean Precipitation RCA driven by ERA-interim

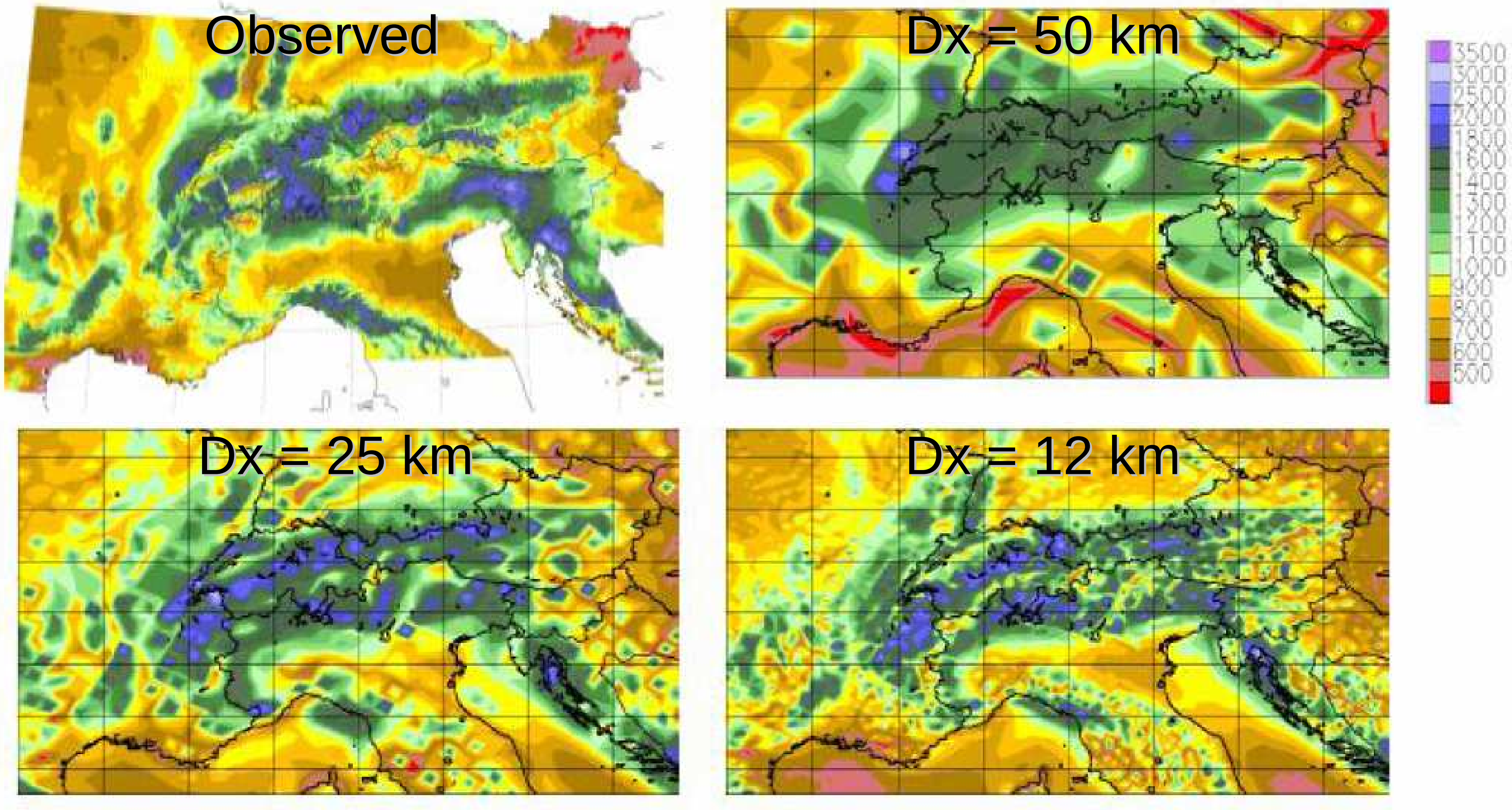




Increasing Regional Climate Model resolution

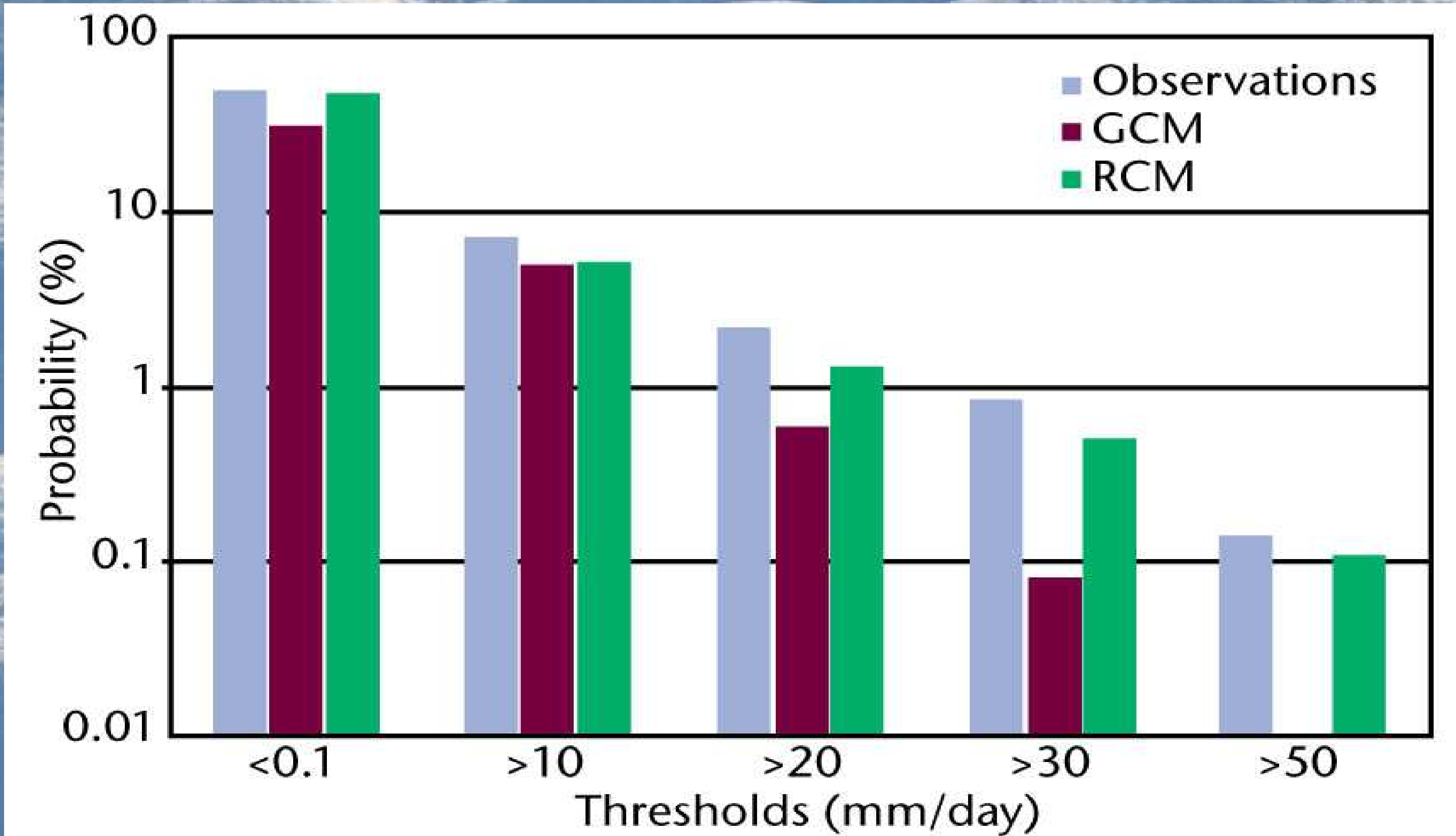
RCM simulation of precipitation over the Alps

Mean annual precipitation (mm/day)



From Christensen et al. 2005

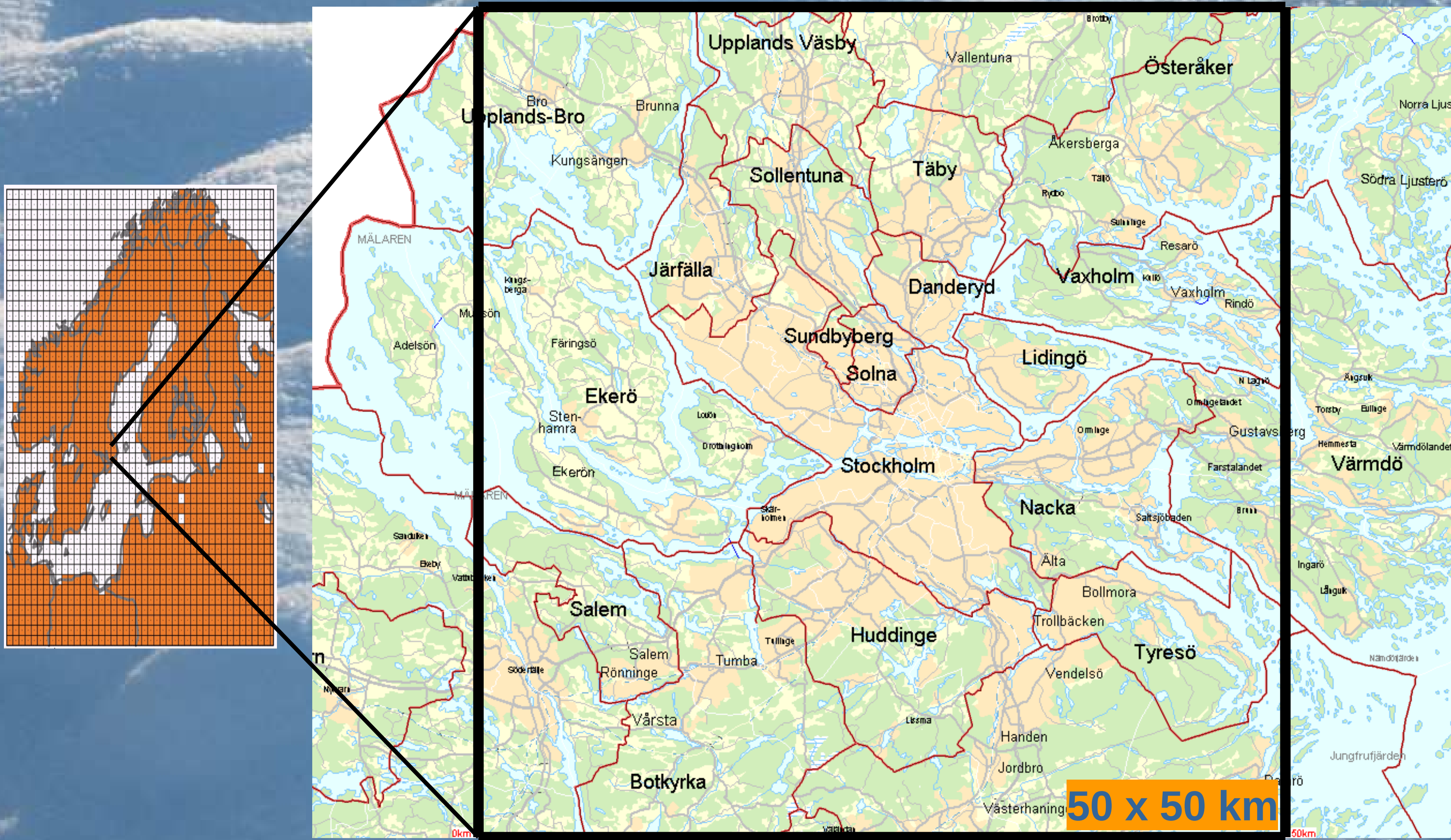
WINTER DAILY RAINFALL OVER THE ALPS



Higher Resolution yields a better description of extreme precipitation

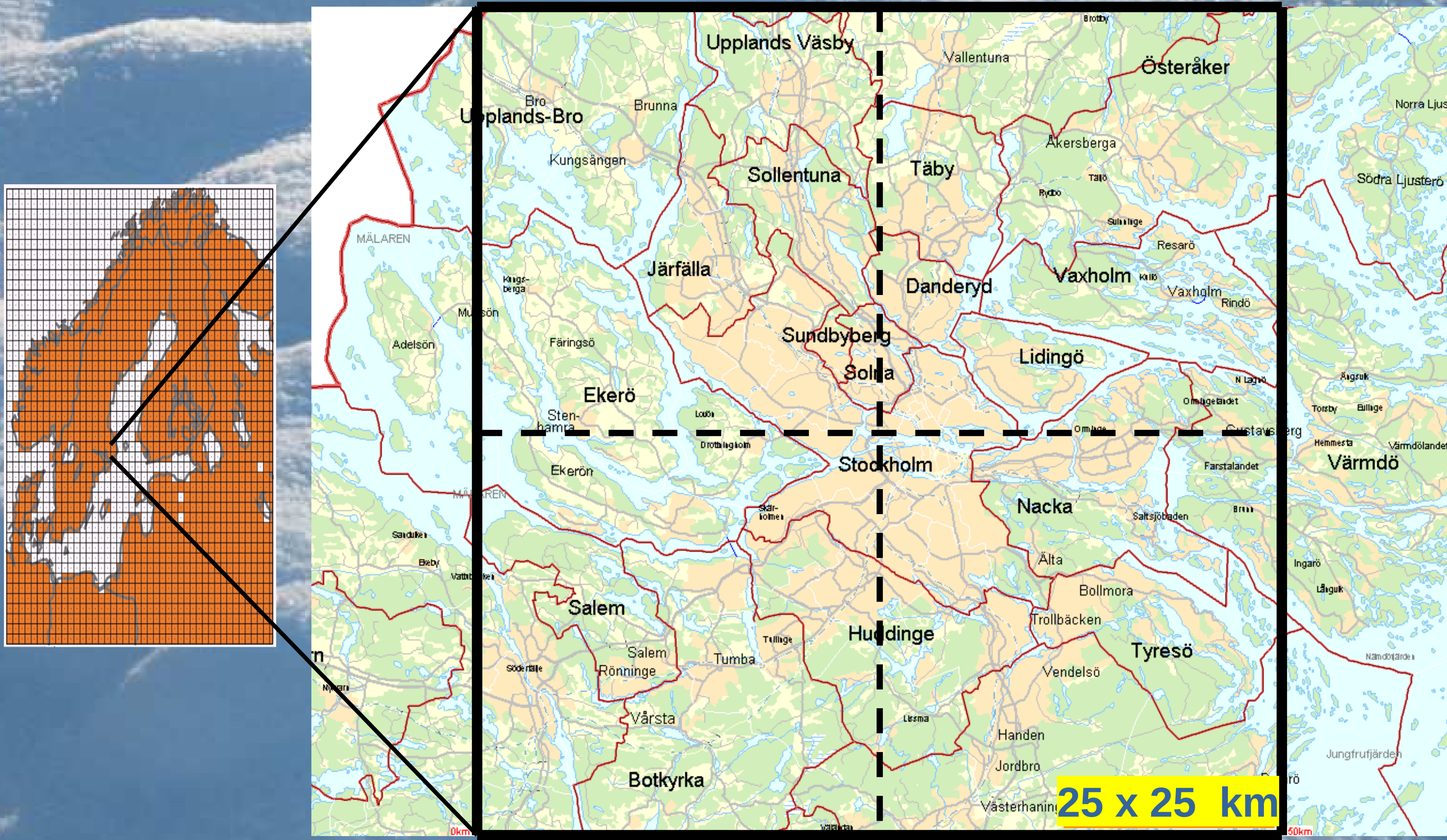
The standard resolution of RCA has been ~50km

Similar to most other RCMs

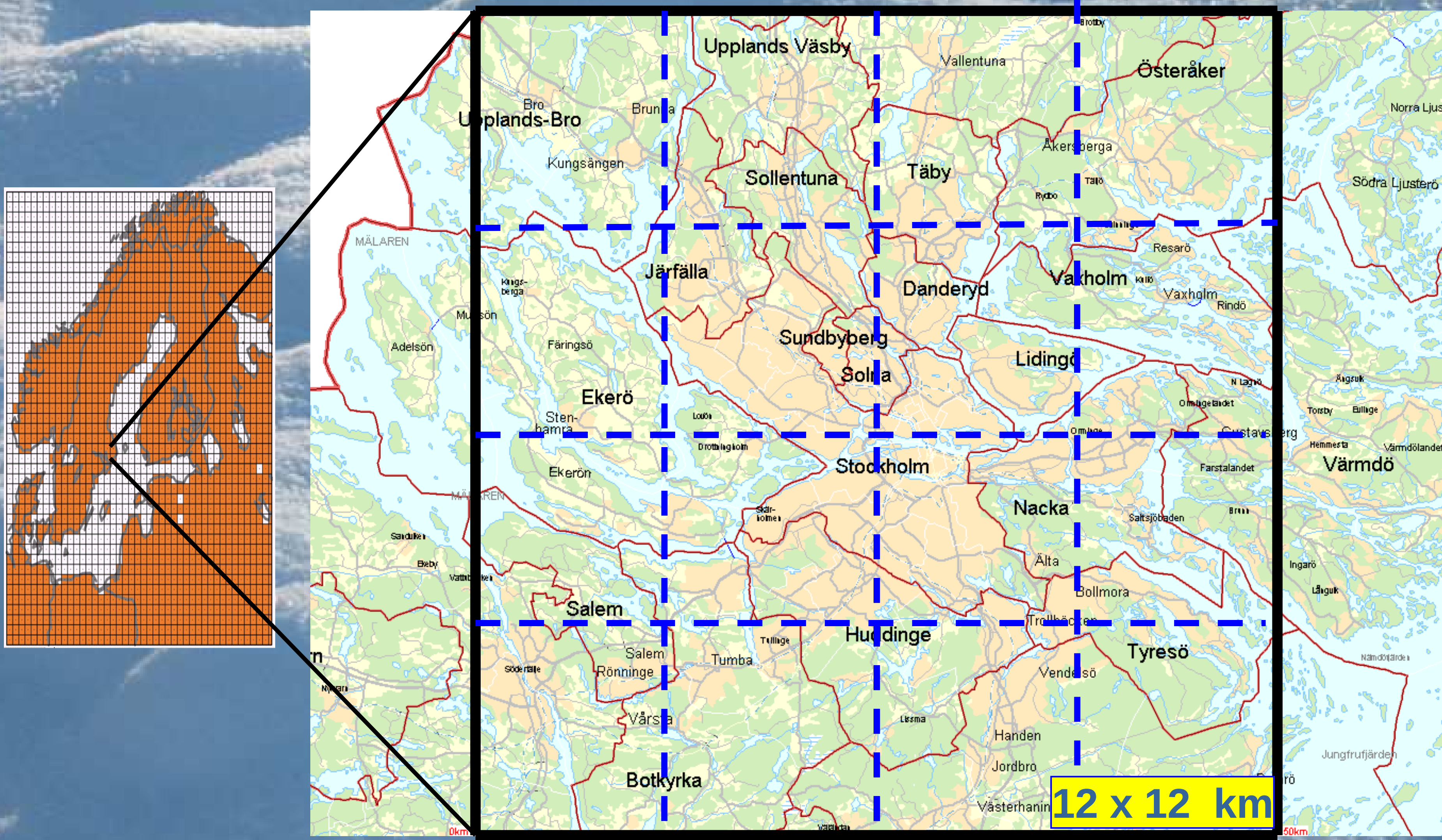


We are presently moving that standard to be ~25km

Similar to most other European RCMs



And have begun testing a 'future standard' of ~12km



Summary

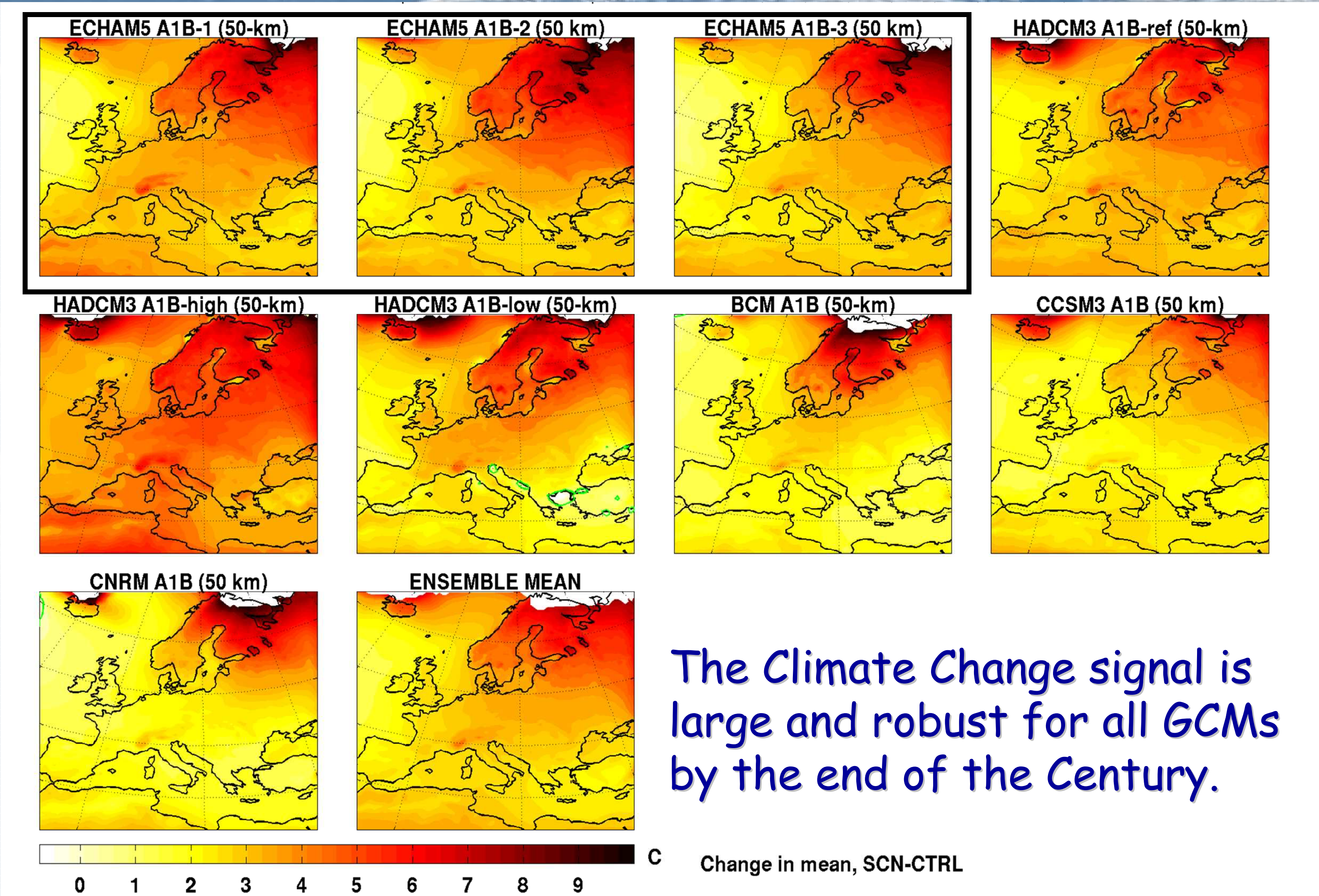
The Rossby Centre is embarking on a new activity in Global Climate Prediction within the EC-Earth consortium

We will continue Regional Climate Modelling : Increasing model resolution (towards ~10km, then ~2-4km (locally)) complexity in terms of physical/biogeochemical processes

Many new regional scenarios will be developed over the coming years: For Europe, Arctic, Africa, South America

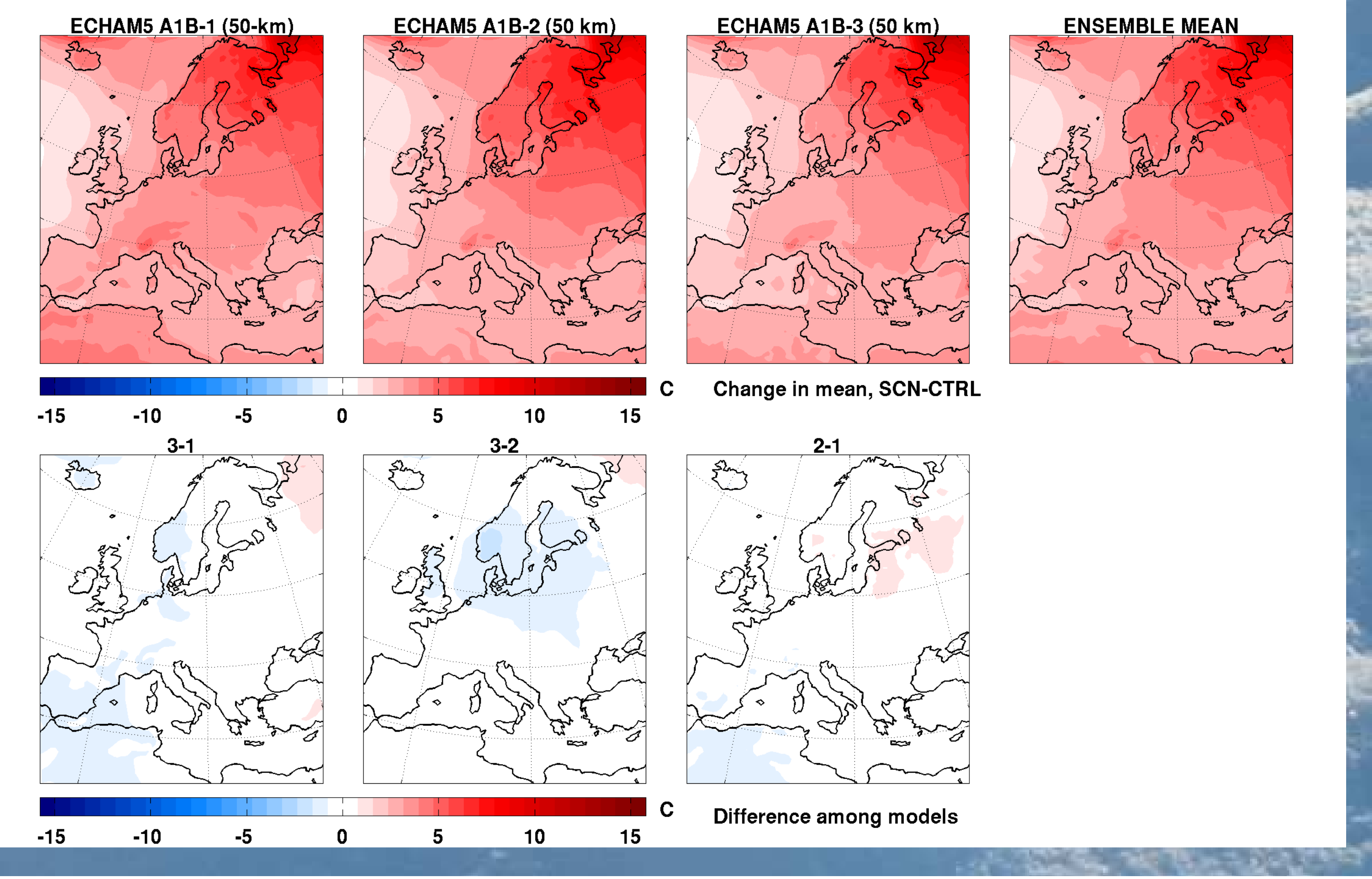
We hope these scenarios will be of interest and help to support your own research and climate related work

Change in winter surface temperature (2061-2090)-(1961-1990) for A1B scenario, as downscaled by a single RCM for a range of GCMs and an ensemble of common GCMs each started from different initial dates



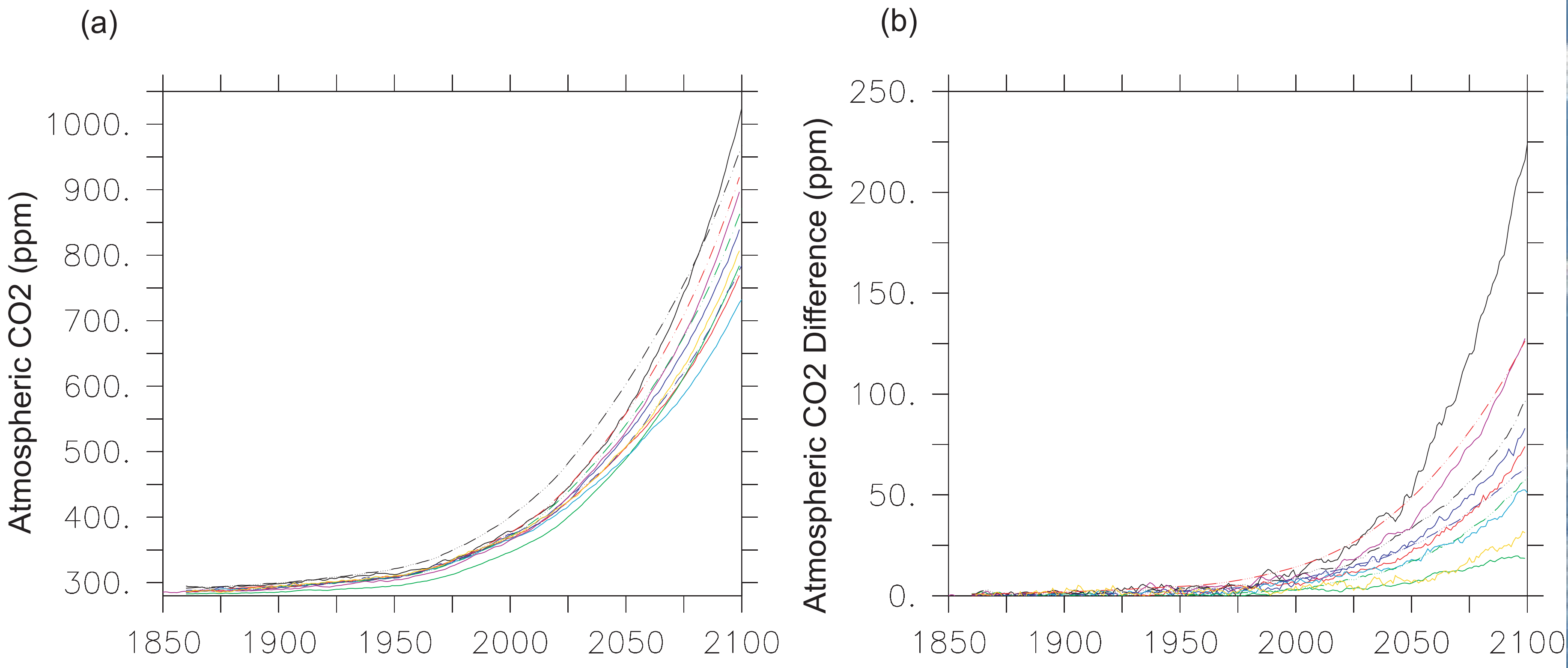
The Climate Change signal is large and robust for all GCMs by the end of the Century.

Comparing 3 RCM runs all using the ECHAM5 A1B GCM as boundary forcing but with each ECHAM5 run started from a different initial conditions drawn from the ECHAM5 control run and assigned the date 1860, allows for an estimate of the variability of the simulated climates in 2061-2090.



The model estimate of natural variability (as defined by different initial dates) is a lot smaller than the forced climate change signal by 2075

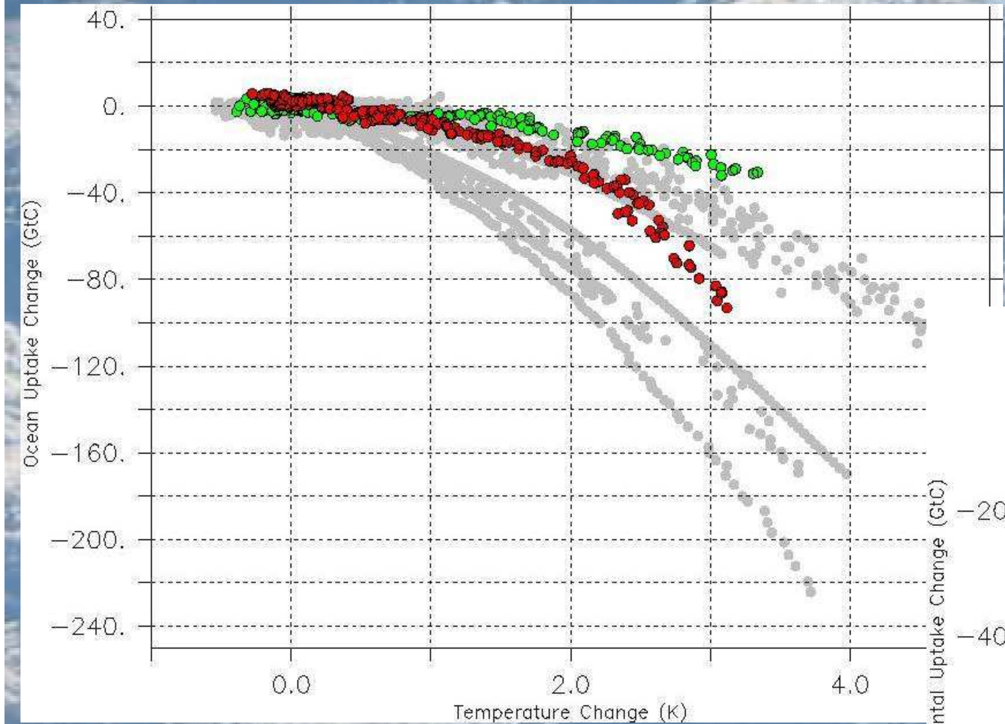
Coupled Carbon Cycle – Climate Models indicate a likely amplification of atmospheric CO_2 concentrations (~5-20%) and climate warming due to the sensitivity of global carbon uptake to physical climate change



Friedlingstein et al., 2006

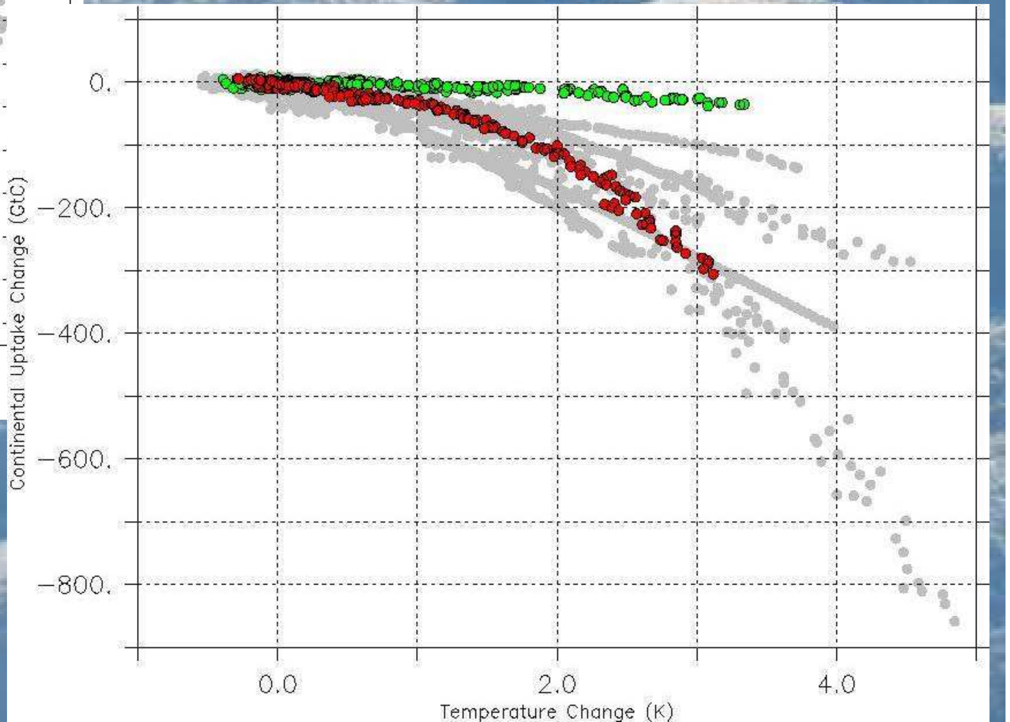
The uncertainty is large due to being dependent on both the simulated physical climate change and the carbon cycle response to this change.

Change in Ocean and Terrestrial Carbon Uptake as a function of simulated climate warming



OCEAN

LAND



IPSL-CM2_C

IPSL_CM4_LOOP

Friedlingstein et al., 2006