# RT1

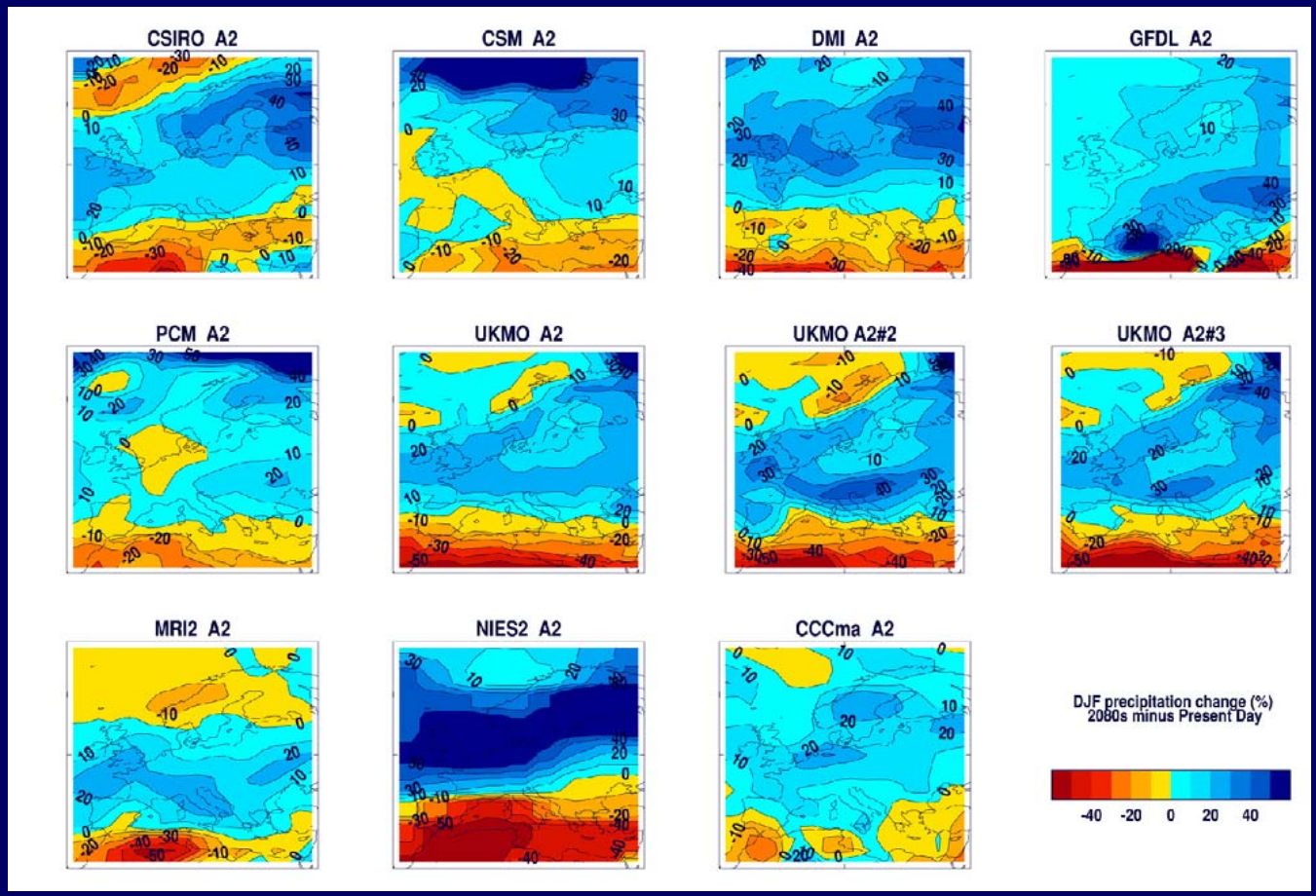
# Development of the Ensemble Prediction System

## Aim

Build and test an ensemble prediction system based on global Earth System models developed in Europe, for use in generation of multi-model simulations of future climate in RT2

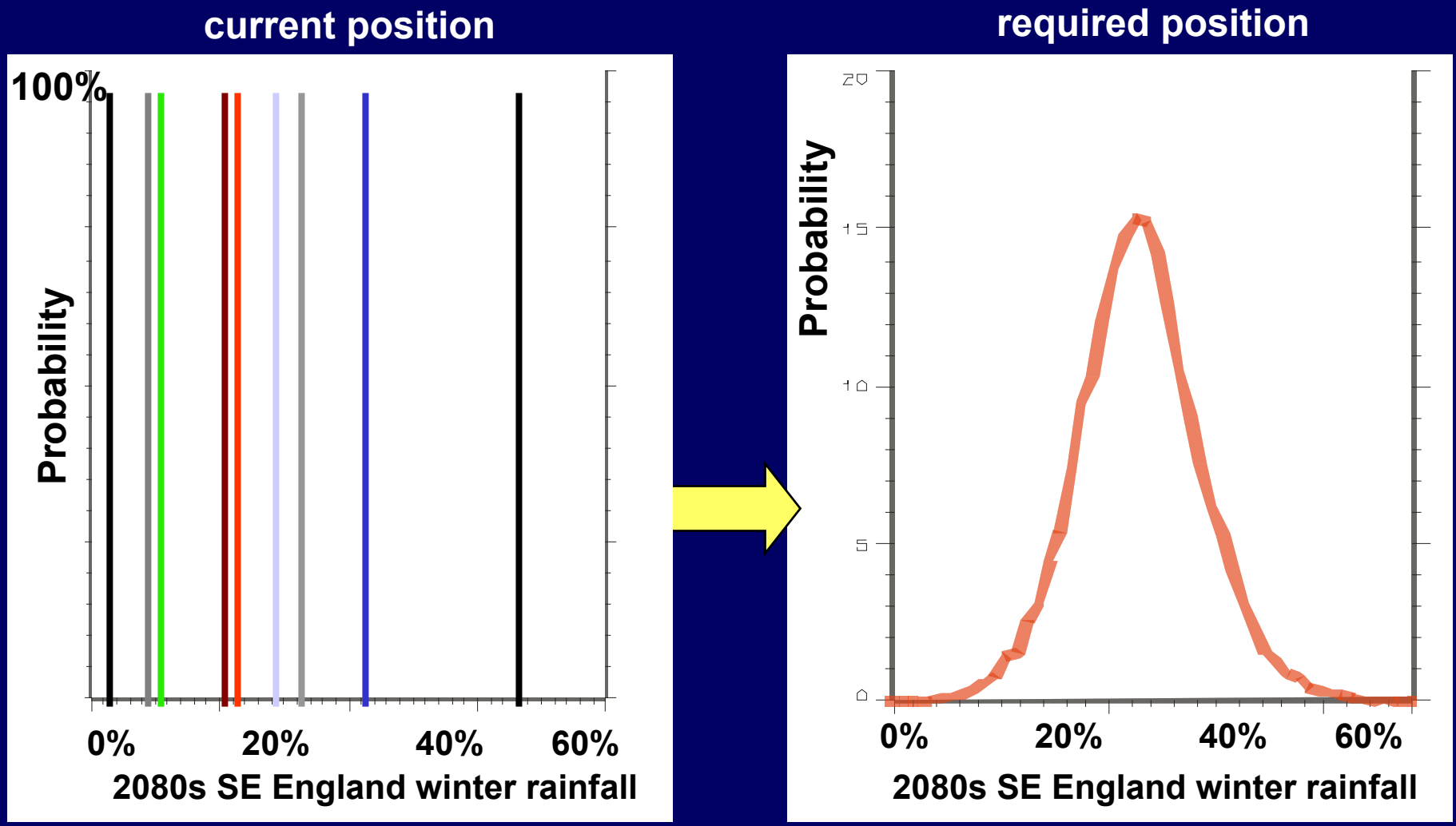
*Coordinators: James Murphy, Tim Palmer*

# Status of Long Term Climate Change Prediction




We can produce a small number of different predictions with no idea of how reliable they might be

# PROBABILISTIC CLIMATE PREDICTIONS



# What distinguishes an ensemble prediction "system" from an ensemble prediction ?

- **Large ensembles**
- **A systematic, traceable and comprehensive approach to sampling uncertainties**
- **Methods of converting ensembles of model simulations into probabilistic predictions**
- **Objective methods of justifying the forecast probabilities**

# Ensemble climate prediction for different time scales

## Seasonal to Decadal Predictions

- Initial value problem, external forcing may be important too.
- Probabilistic hindcasts can be verified

## Decadal to Centennial Predictions

- External forcing problem, initial conditions may be important too.
- Probabilistic hindcasts cannot be verified

# Version 1 of Ensemble Prediction System

- Recommended design by month18, specified system by month 24.
- Will be used by RT2A to generate a second stream of “production” global climate simulations in years 3 and 4
- Will comprise separate systems for seasonal to decadal and multi-decadal prediction

# Version 2 of Ensemble Prediction System

- Specifed system at month 60
- Will seek to extend the range of uncertainties sampled
- Improved methods of constructing probabilistic predictions
- Based on the concept of a single, generalised system for seasonal to centennial prediction ?

Y = uncertainties fully sampled by the end of ENSEMBLES

y = uncertainties partially sampled by the end of ENSEMBLES

y = uncertainties partially sampled at the start of ENSEMBLES

| | Structural | Parameter | Stochastic |
|---|---|---|---|
| Atmospheric physics | y | y | y |
| Ocean physics | y | y | |
| Terrestrial carbon cycle | y | y | |
| Ocean carbon cycle | y | | |
| Sulphur cycle | y | y | |
| Other atmospheric chemistry | y | | |

ENSEMBLES will be a major step forward ..but ensemble climate prediction will not be a solved problem by the end of the project…….

# Defining Version 1 of the Seasonal to Decadal System

- Will compare 3 different methods of sampling modelling uncertainties
- Multi-model ensemble (7 models)
- Ensemble of versions of one model (HadCM3 with perturbed parameters)
- Sampling of stochastic parameterisation uncertainties in one model (ECMWF)
- Will also consider initial condition uncertainties (9 member ensembles)

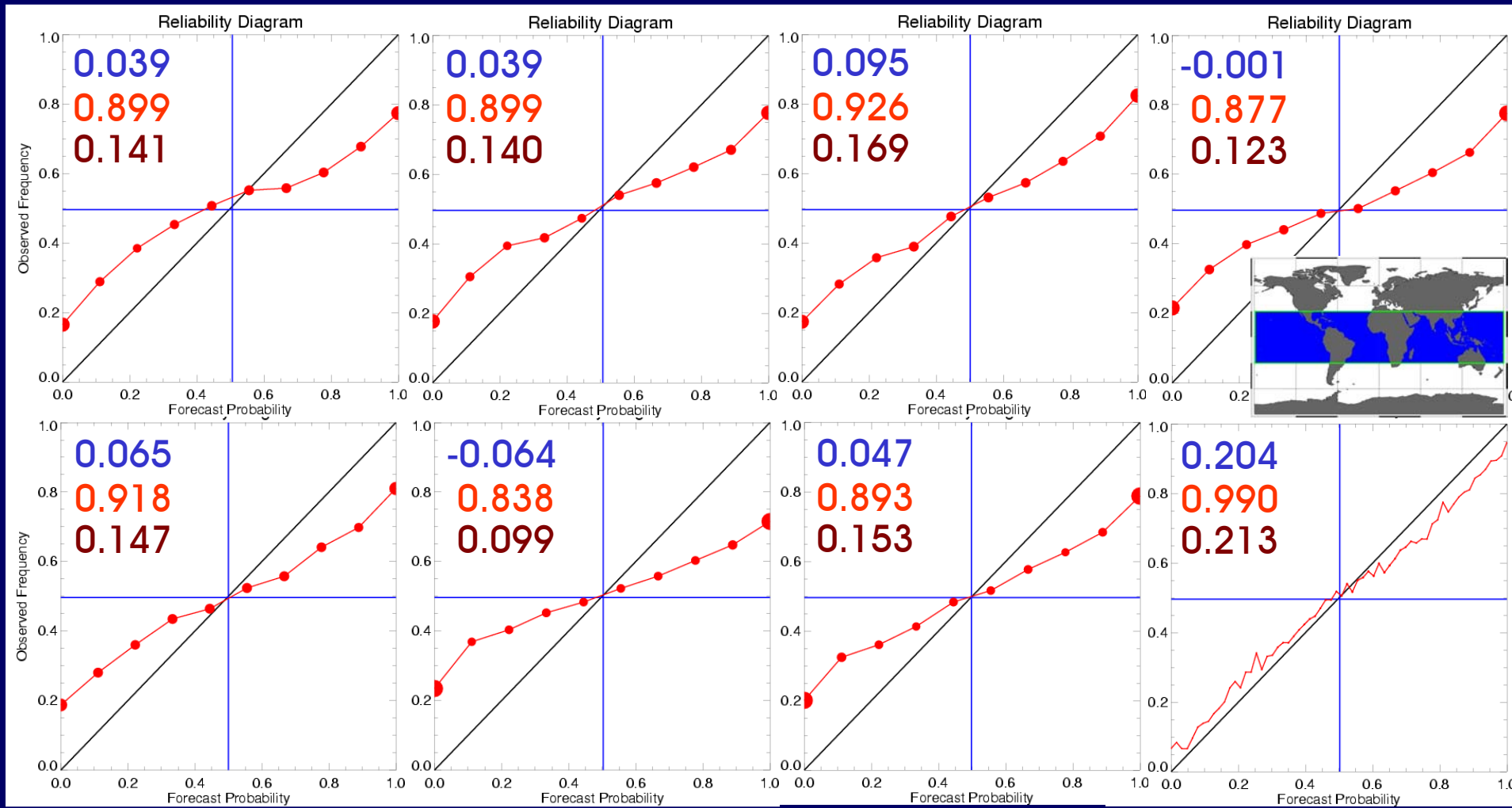
# RT1 Seasonal to decadal experiments

- Use of the multi-model, perturbed parameters and stochastic physics methods to estimate forecast uncertainty in a co-ordinated experiment.
- Pre-production (initial 18-months) for the period 1991-2001 with two 6-month (starting in May and November) and one annual ensemble integrations.
- Pre-production multi-annual integrations with start dates in 196x and 199x.
- Ocean initial conditions from EU-funded project ENACT and generation of new sets when possible.
- Common output archived at ECMWF.

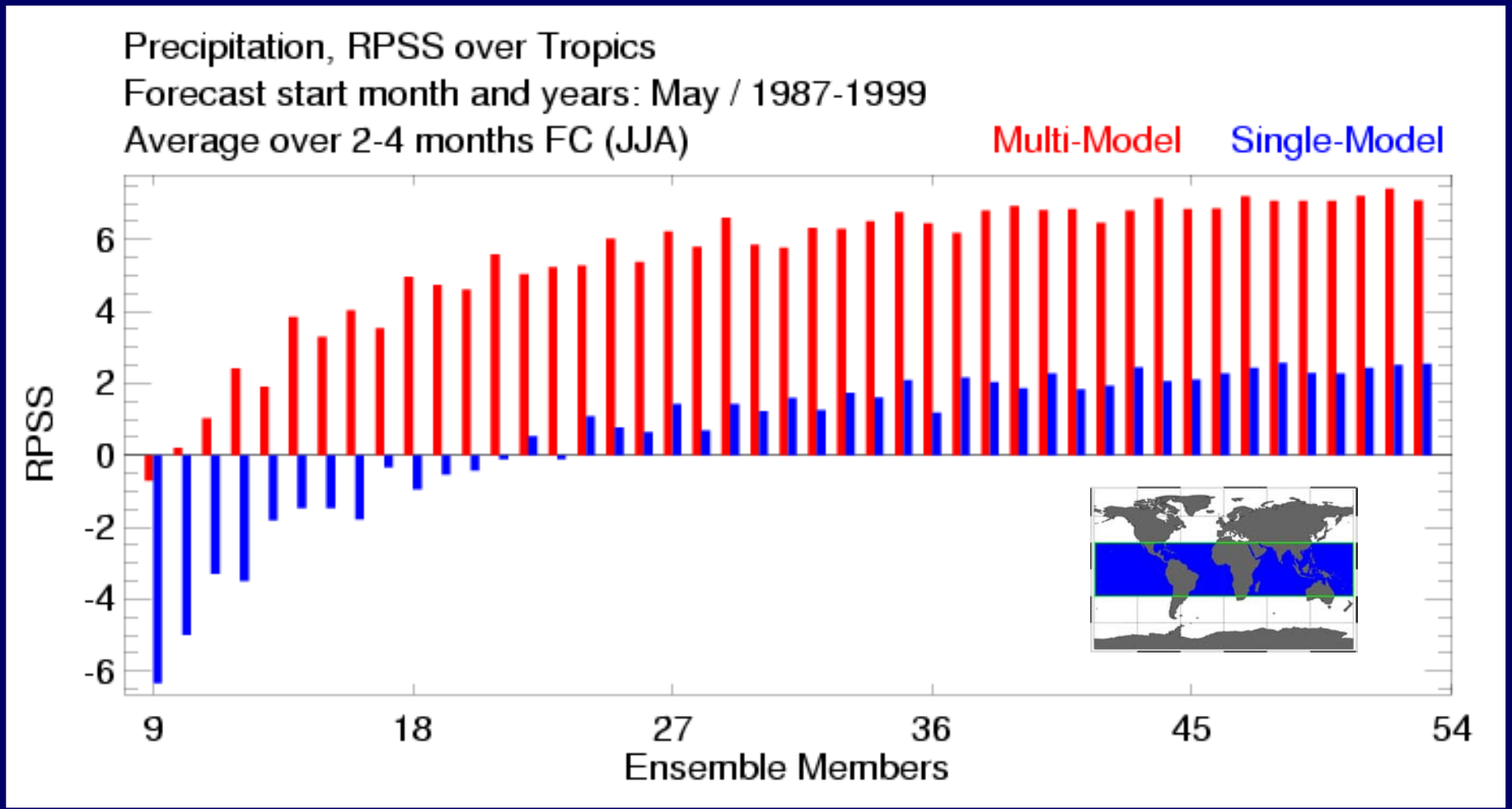
# DEMETER Multi-model: Reliability

BSS
Rel-Sc
Res-Sc

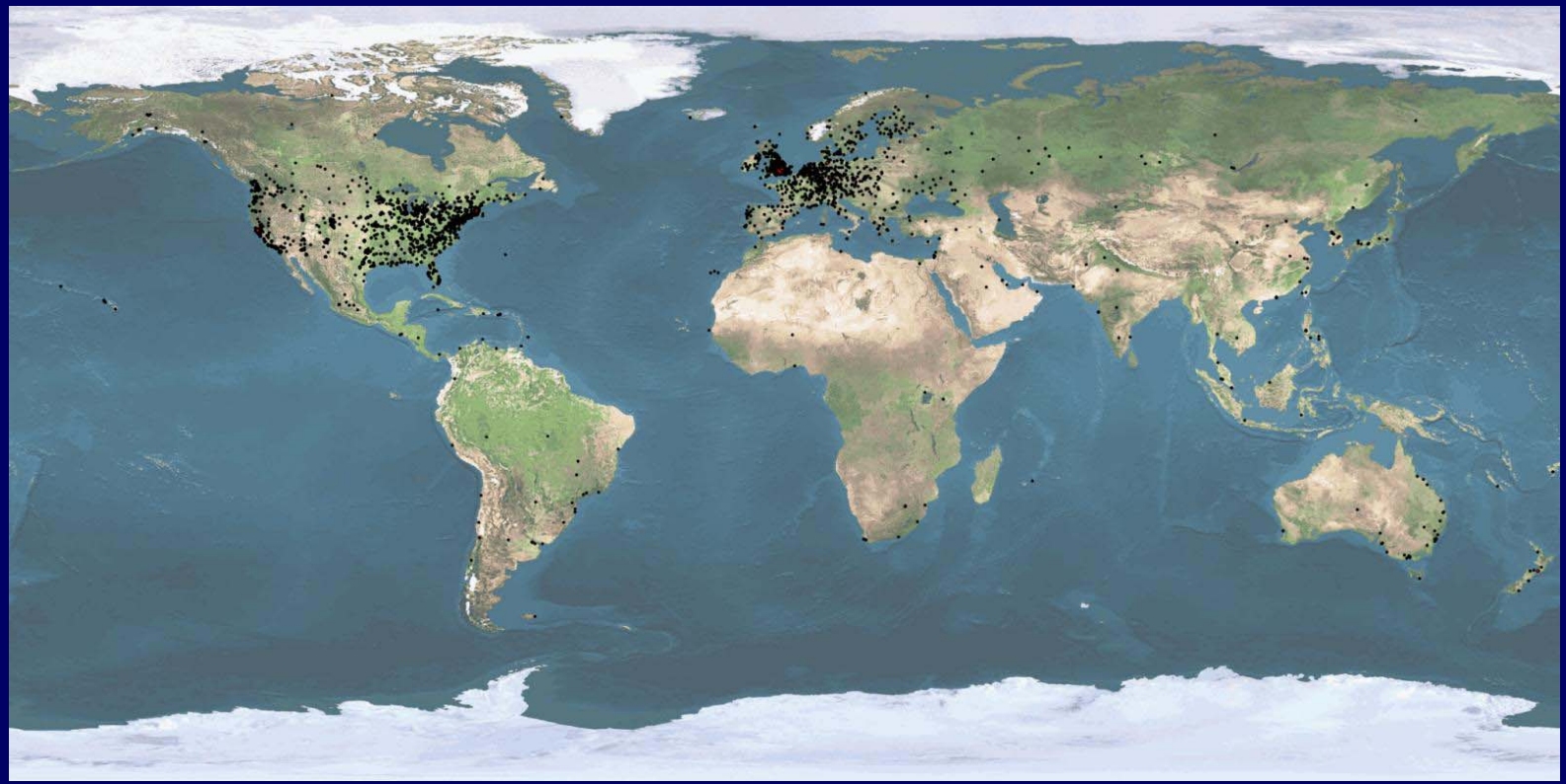
Reliability for T2m>0, 1-month lead, May start, 1980-2001



# DEMETER Multi-model: Impact of ensemble size



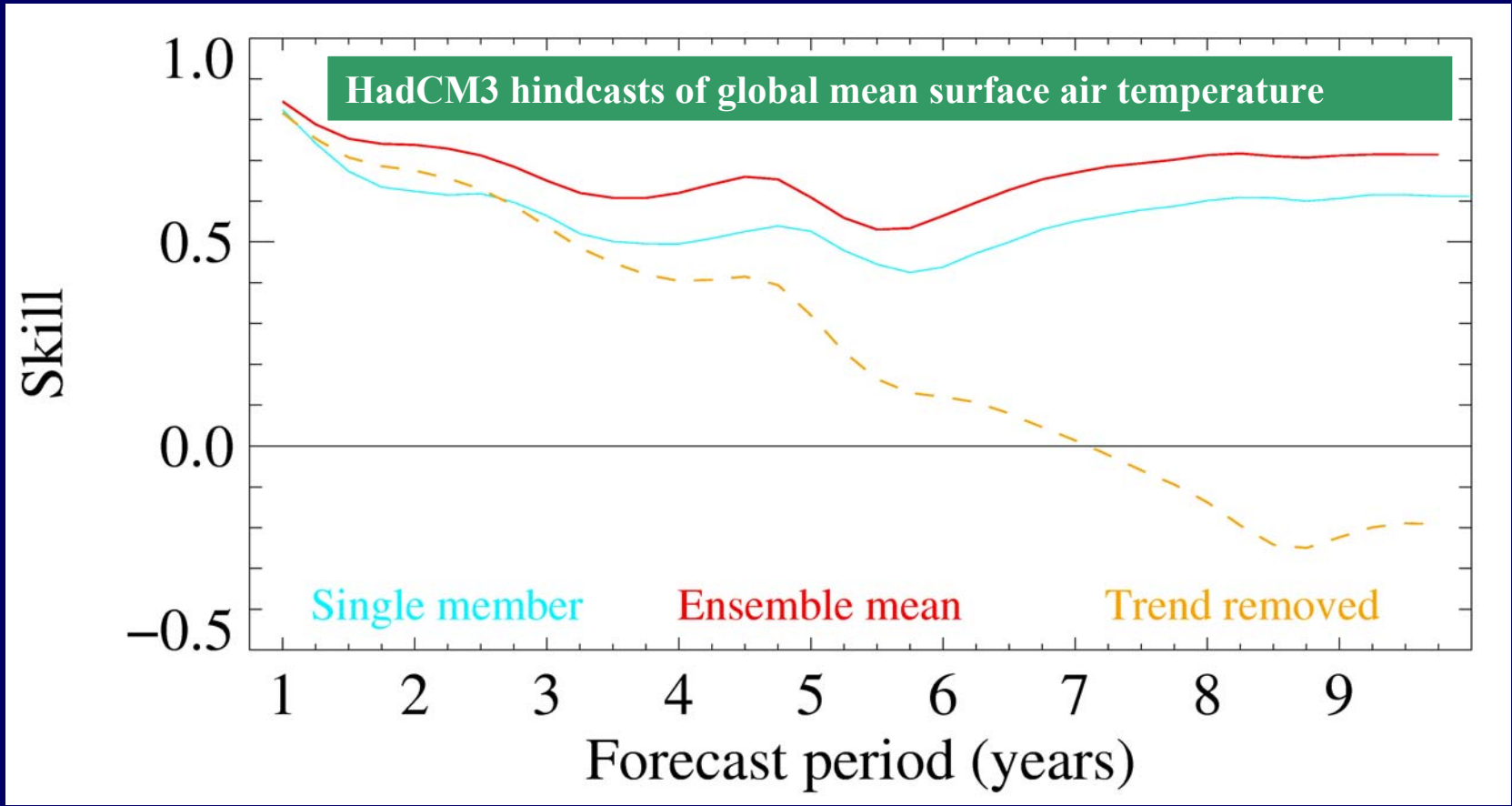
# University of Oxford contribution to ENSEMBLES through climate*prediction*.net : a global facility for ultra-large AOGCM ensembles



- Beta-test of coupled HadCM3/HadCM3L ensemble by end 2004.
- Initial coupled experiment: large initial-condition ensemble, using ENSEMBLES community PCs?

# Decadal Prediction Methodology

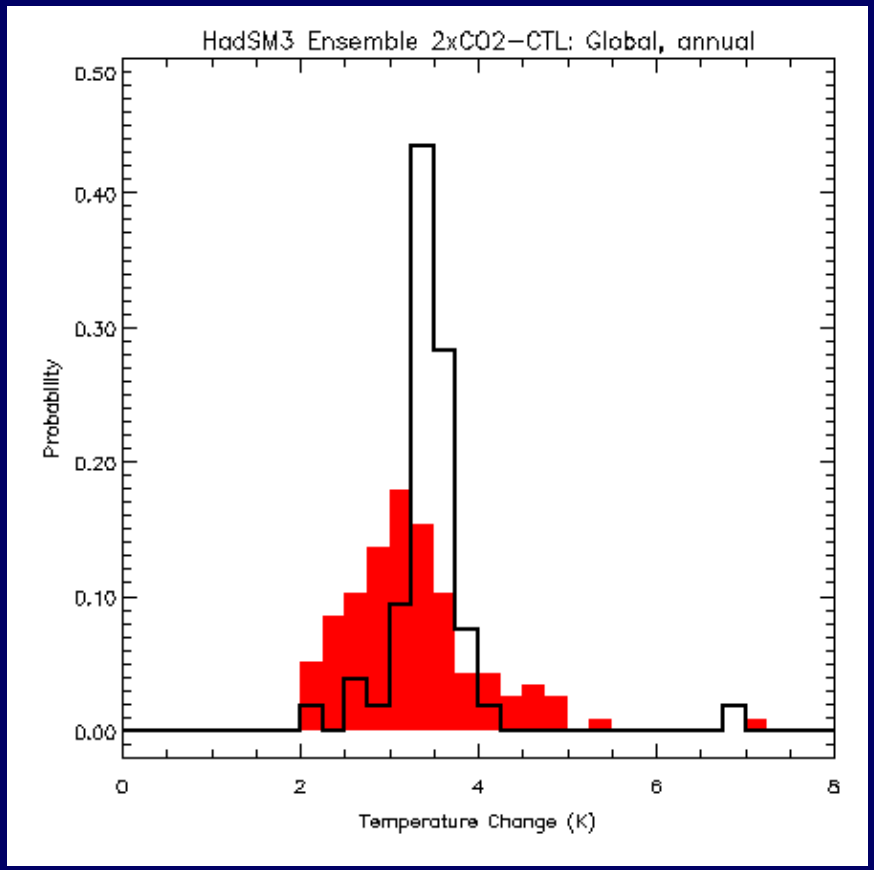
- Need to initialise from observed conditions
- *And* need to include external forcings (GHGs, aerosols, volcanoes, solar,..)



# Defining Version 1 of the Centennial System

- A perturbed parameter ensemble of HadCM3 will be generated and compared against the first multi-model ensemble of RT2A
- The HadCM3 ensemble will consist of:
- 1860-2100 simulations with 16 HadCM3 versions with multiple perturbations to uncertain surface and atmospheric parameters
- Augmented by additional pseudo-transient simulations obtained by scaling the equilibrium responses of 128 2x$CO_2$ simulations of the “slab” version of HadCM3

# Climate sensitivity in a large perturbed parameter ensemble

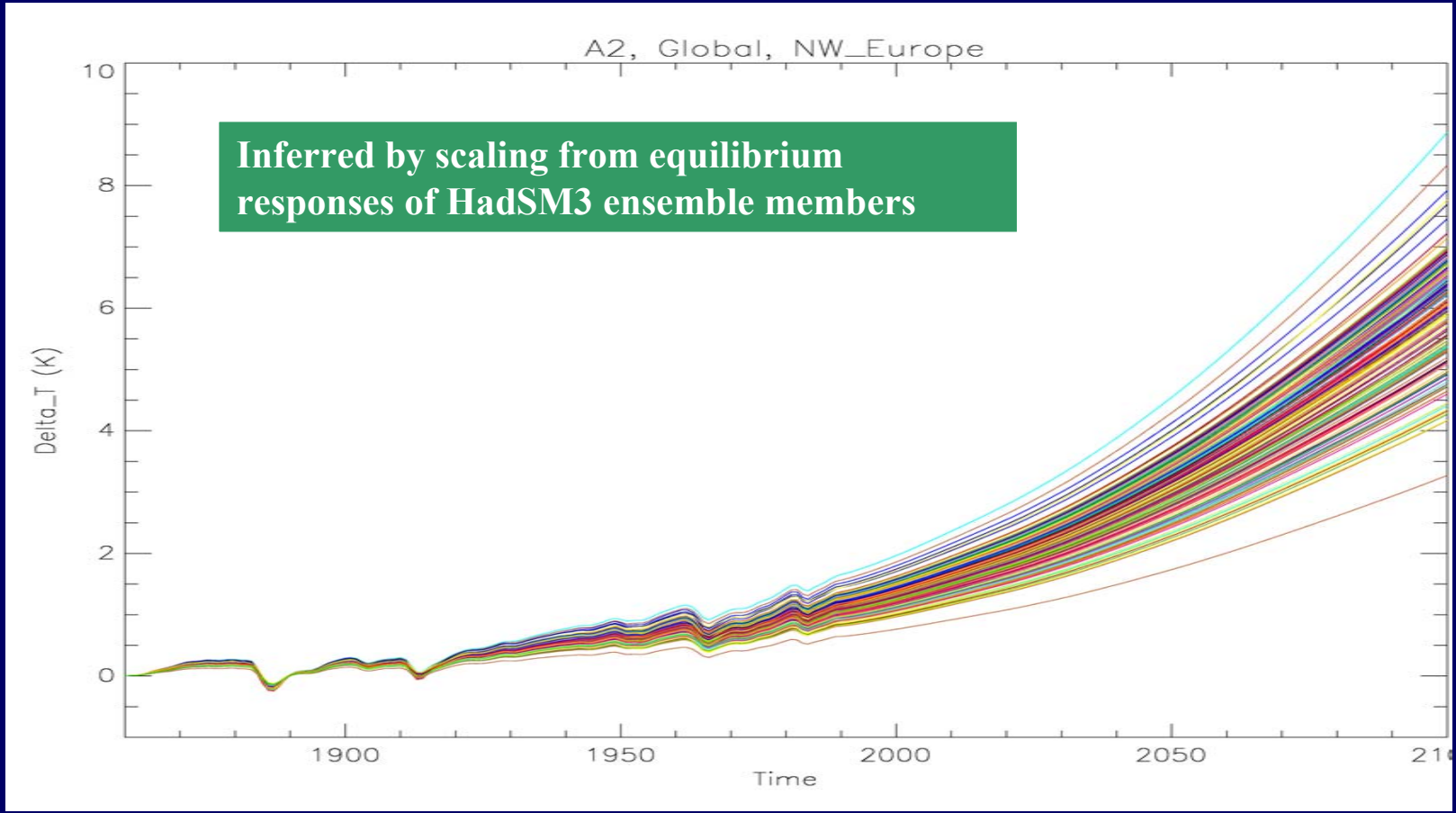



Multiple parameter perturbations (128 runs)

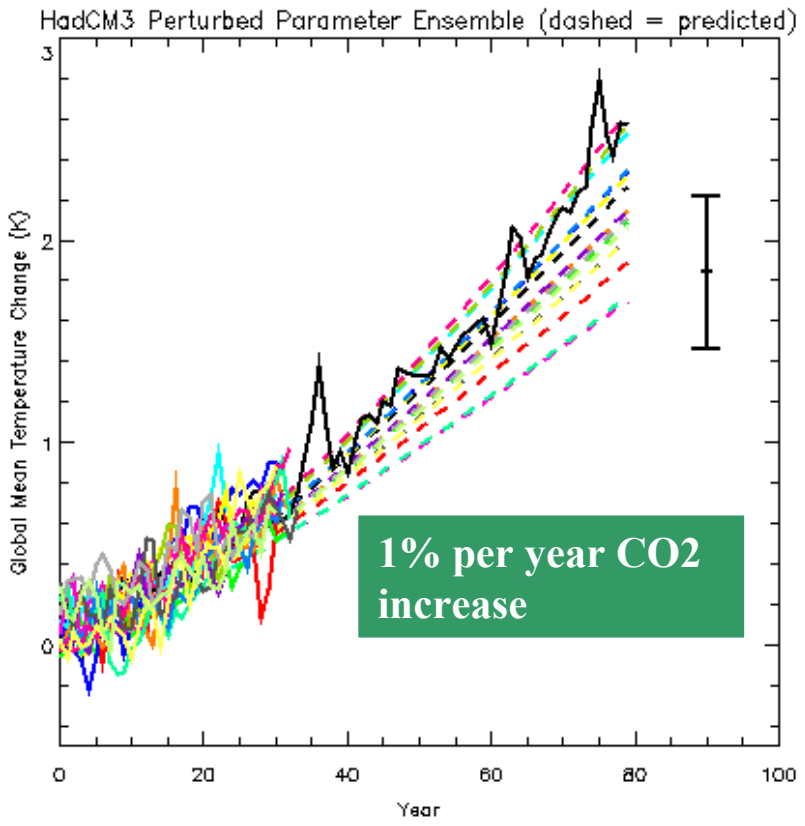
Single parameter perturbations (53 runs)

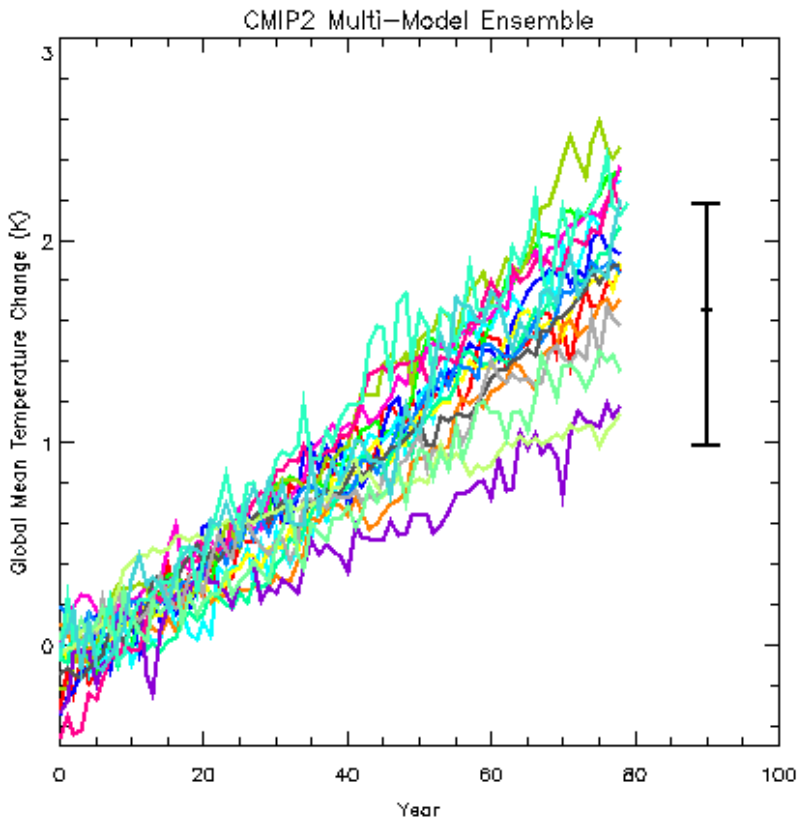
Red histogram shows results from a new ensemble of 128 HadSM3 (slab) model versions designed to produce good present day climate simulations while maximising coverage of parameter space and climate sensitivity

# Example Output:
# NW Europe temperatures under A2 scenario



# Coupled Model Ensembles




HadCM3 perturbed physics

CMIP2 multi-model

# Evaluating Centennial Ensemble Prediction Systems

- Predictions cannot be verified
- So how do we know when we've got the best possible system ?

- Sampling the widest possible range of modelling uncertainties
- Sampling the space consistent with observational constraints
- Reliable probabilities on the seasonal-decadal time scale as a necessary condition for trusting the system in centennial prediction

# RT1 Workpackages

- 1.0: Management
- 1.1 Construction of Earth System Models
- 1.2 Methods of representing uncertainty
- 1.3 Initialising the ocean
- 1.4 Assembling the multi-model system
- 1.5 “pre-production” seasonal to decadal predictions
- 1.6 “pre-production” centennial predictions

# 1.1 Construction of Earth System Models

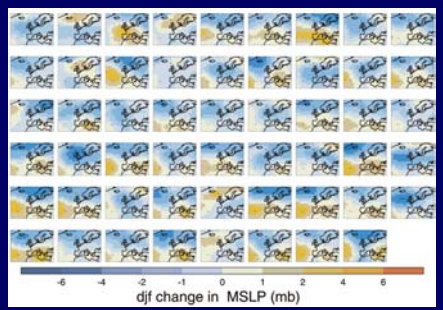
- Put together a number of ESMs from existing modules
- Demonstrate performance in test simulations
- (CNRM, Free Univ Berlin, Hadley Centre, MPI, DMI, IPSL)
- Available for reassembly in different combinations using PRISM
- Available for use in systematic perturbation experiments

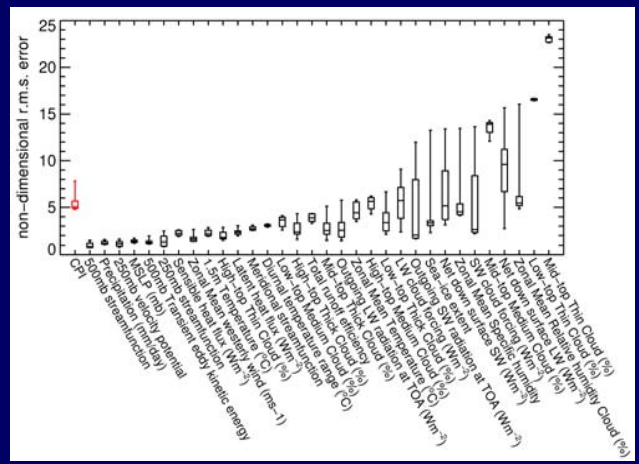
**Major Milestone**

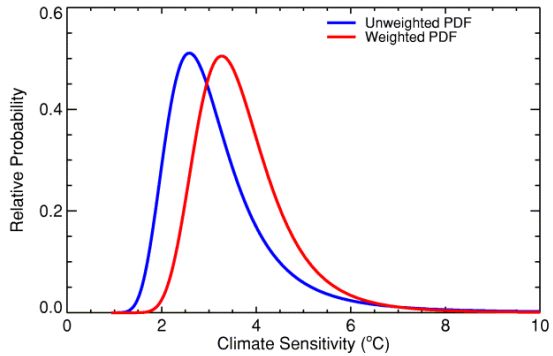
**A set of tested ESMs available for use in the ensemble prediction system by month 24.**

# 1.2 Methods of representing uncertainty

- How to perturb model processes
- How to weight models according to reliability
- How to combine different approaches




**Design ensemble** → **Apply metric of reliability** → **Generate probabilistic prediction**

# 1.3: Ocean initialisation procedures based on observed states

Objective:

- To develop techniques to initialise ESMs and to represent uncertainties in the ICs for the ESM integrations

Content:

- Initialization techniques will be based on advanced data assimilation systems (variational, EnKF, OI) developed under ENACT.
- Extension of ENACT data-set of quality-controlled *in situ* observations.
- Development of an ensemble generation strategy to account for IC uncertainties.

  Possibilities include:

  - Using individual systems to generate ensembles of ocean analyses by perturbing surface forcing fields, observations and/or model equations.
  - Using the analyses generated by the different assimilation systems to define the ensemble.

# Some Issues for Discussion in RT1

- Coordination with other RTs (especially RT2)
- Facilitate comparison of multimodel and perturbed physics ensembles
  - Data from model integrations
  - Emissions/forcing scenarios
- Scoring metrics for seasonal to decadal ensembles
- Quality metrics for centennial ensembles
- Strategy for perturbation of ocean initial conditions
- Methodology and choice of dates for decadal predictions
- A large initial condition ensemble from climate*prediction*.net ?
- Website
- … and more …