RT1 Progress and Plans

Coordinators: James Murphy, Tim Palmer

Development of an 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

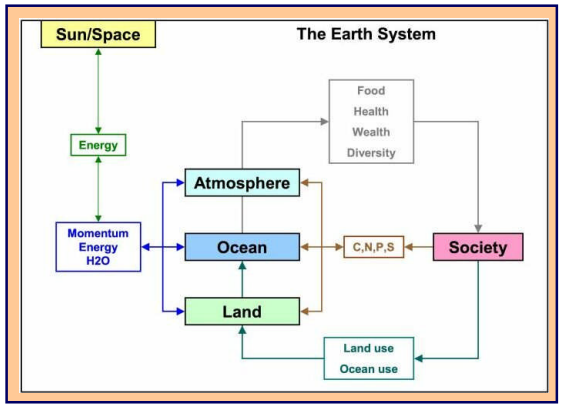
Version 1 of Ensemble Prediction System

- 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

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

Potentially an Earth system model can be arbitrarily complex ⟷



ENSEMBLES needs ensembles of "ESMs" of reasonable size

Issues:

- Intended use (seasonal, decadal, centennial) vs. complexity
  Example: carbon cycle not relevant for seasonal predictions
- Available models: many "simple" models vs. a few complex ESMs
- Time and computer limits:
  expensive models → small ensemble of integrations

Possible solution: build ensembles of different model classes, e.g.:
physical system, carbon cycle system, aerosol system

WP1.1 Status at month 12 (of 24)

- A new generation of coupled atmosphere ocean models based on the existing components has been developed and tested
- More complex models include aerosol components or chemistry or the carbon cycle
  - Some in development/testing stage
  - Some employed already for IPCC / “Stream 1”
- Perturbed parameters are tested in the HadCM3 model

- Status report in preparation as **Deliverable 1.1**

- Outlook for months 13-24:
  Continuation of model development towards **Major Milestone 1.1**

Seasonal to decadal pre-production experiments

Three different forecast systems to estimate model uncertainty

- Multi-model, built from ECMWF, Met Office, Météo-France operational activities and DEMETER experience.
- Perturbed parameter approach, built from the decadal prediction system (DePreSys) at the Met Office.
- Stochastic physics, built from the stochastic physics systems developed for medium-range forecasting at ECMWF.
- Design of a set of common experiments to determine the benefits of each approach.

Multi-model ensemble system

- ENSEMBLES system: 7 coupled GCMs running at ECMWF

Partner	Atmosphere	Ocean
ECMWF	IFS	HOPE
ECMWF	IFS	OPA
CNRM	ARPEGE	OPA
CERFACS	ARPEGE	OPA
UKMO	GloSea	
UKMO	DePreSys	
MPI	ECHAM5	MPI-OM1

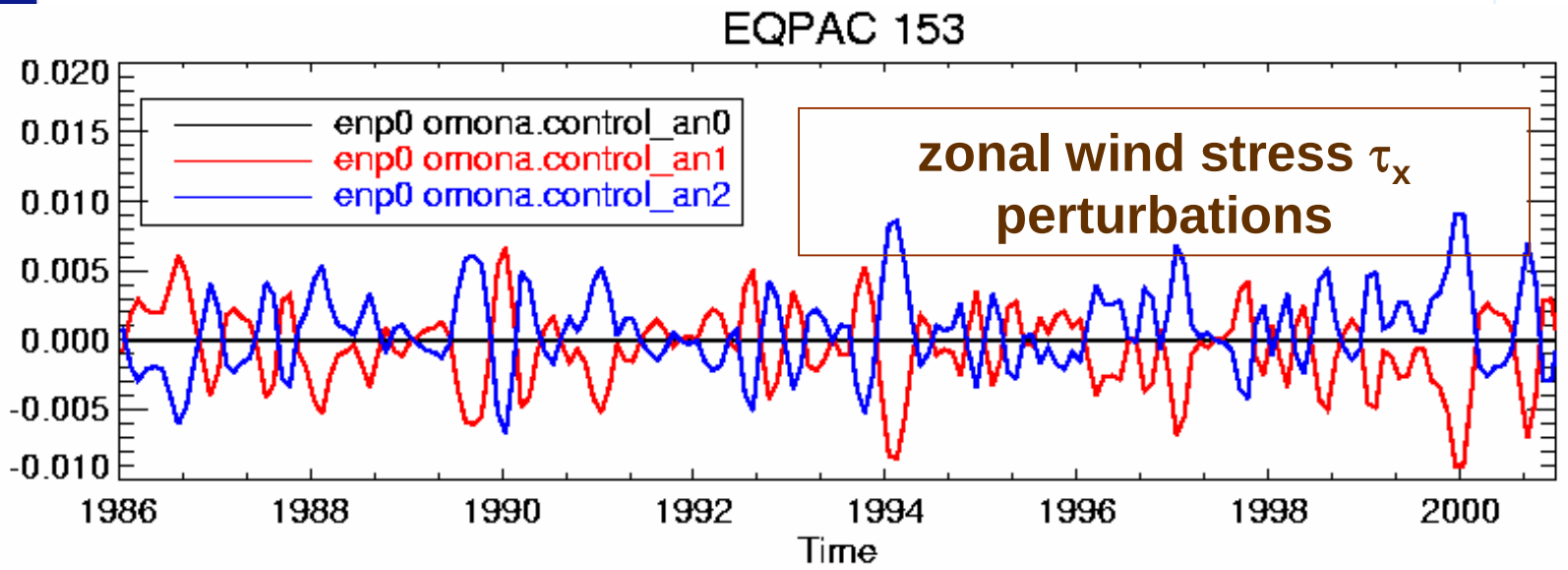
9-member ensembles
ERA-40 atmosphere and soil initial conditions
ENACT-based ocean initial conditions with SST and wind perturbations
2 seasonal (6 months),1 annual (12-14 months)runs per year
Two multi-annual runs (1965, 1994) except 2 per year for DePreSys)
Realistic boundary forcings: GHGs, aerosols, solar forcing, etc.

- Hindcast production period for: 1991-2001

Progress in initialisation and generation of seasonal to decadal pre-production experiments

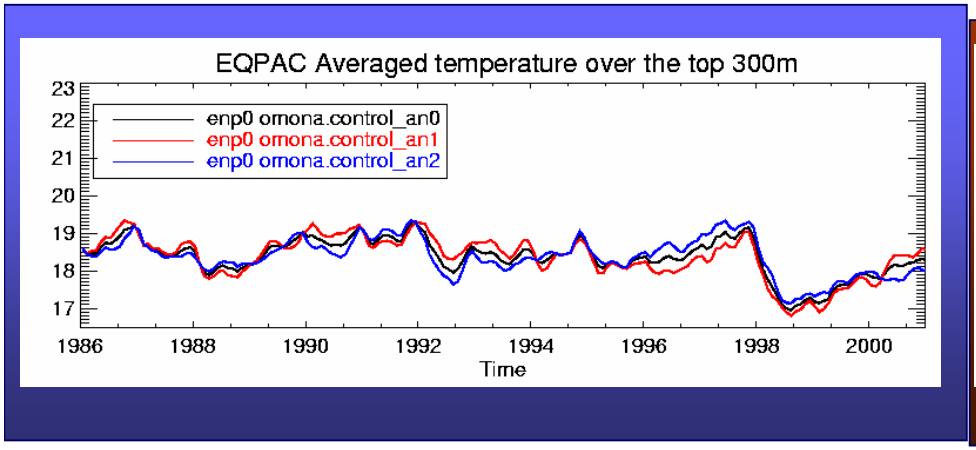
- ENACT database of ocean observations has been upgraded and extended to cover 1958-2004
- Upgrades and testing of systems for the assimilation of ENACT data to initialise the models with ocean observations
- Wind stress and SST perturbation datasets produced to generate alternative initial conditions
- Substantial work done on experimental design for multi-model seasonal to decadal experiments (dates, forcings, data archiving strategy). See RT1 website.
- Models upgraded and installed on the ECMWF supercomputer
- Development of stochastic physics and perturbed parameter methods
- Pre-production experiments have started
- Currently on track to meet deliverables.

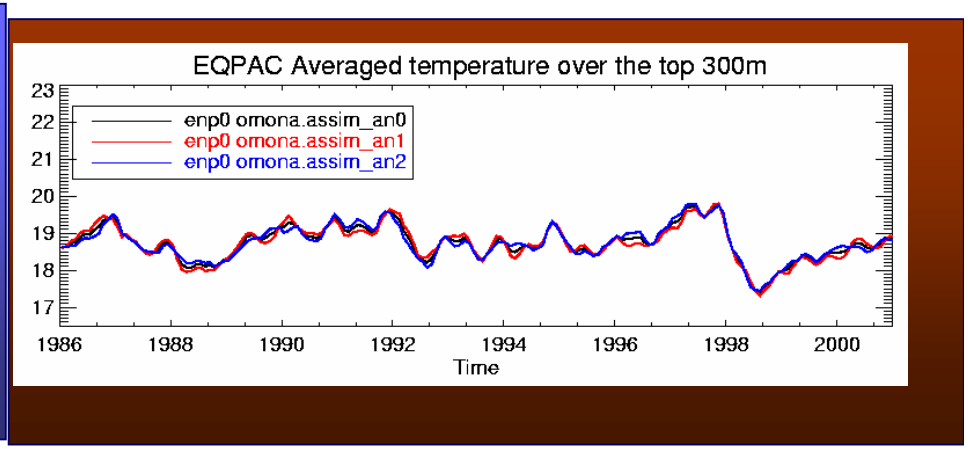
Ocean initial conditions: equatorial Pacific



zonal wind stress τ_x perturbations

T300



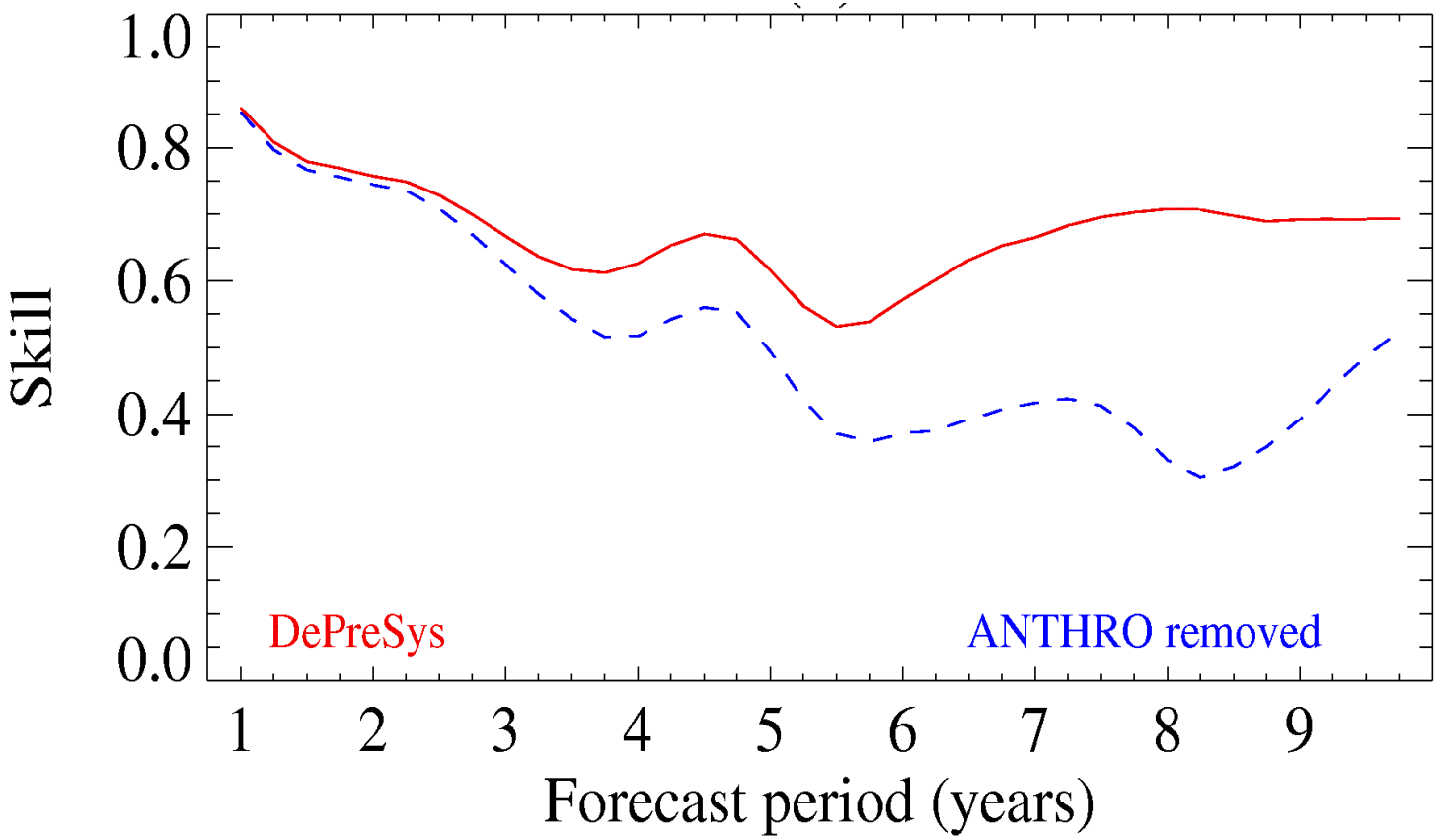


no assimilation

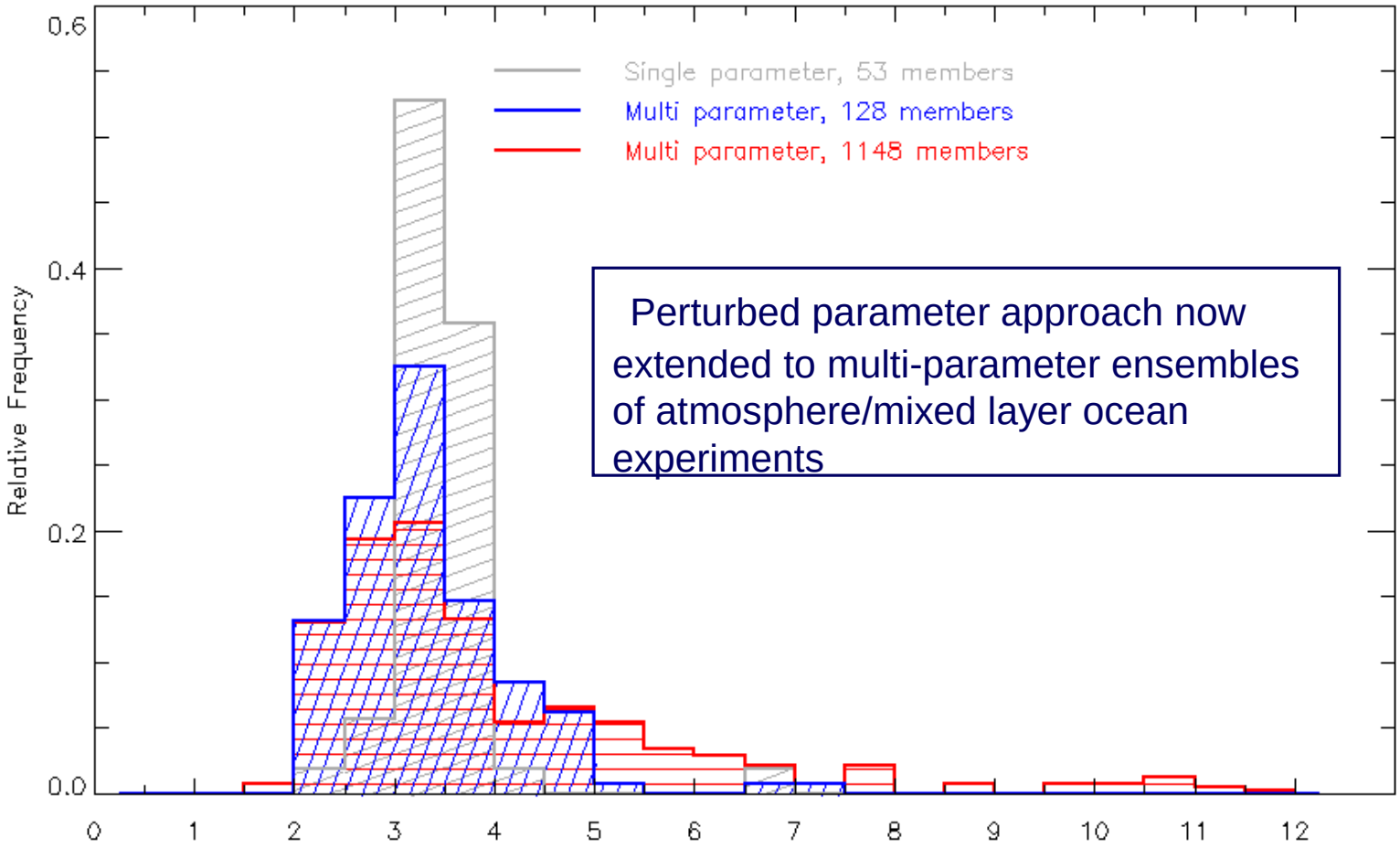
assimilation

Hindcasts of global annual mean surface temperature

8 member HadCM3 ensembles initialised from ocean and atmosphere anomalies observed during 1979-2001
Includes forcings: GHG, aerosol and projections of volcanic and solar



Progress in simulating long term climate change using perturbed physics ensembles

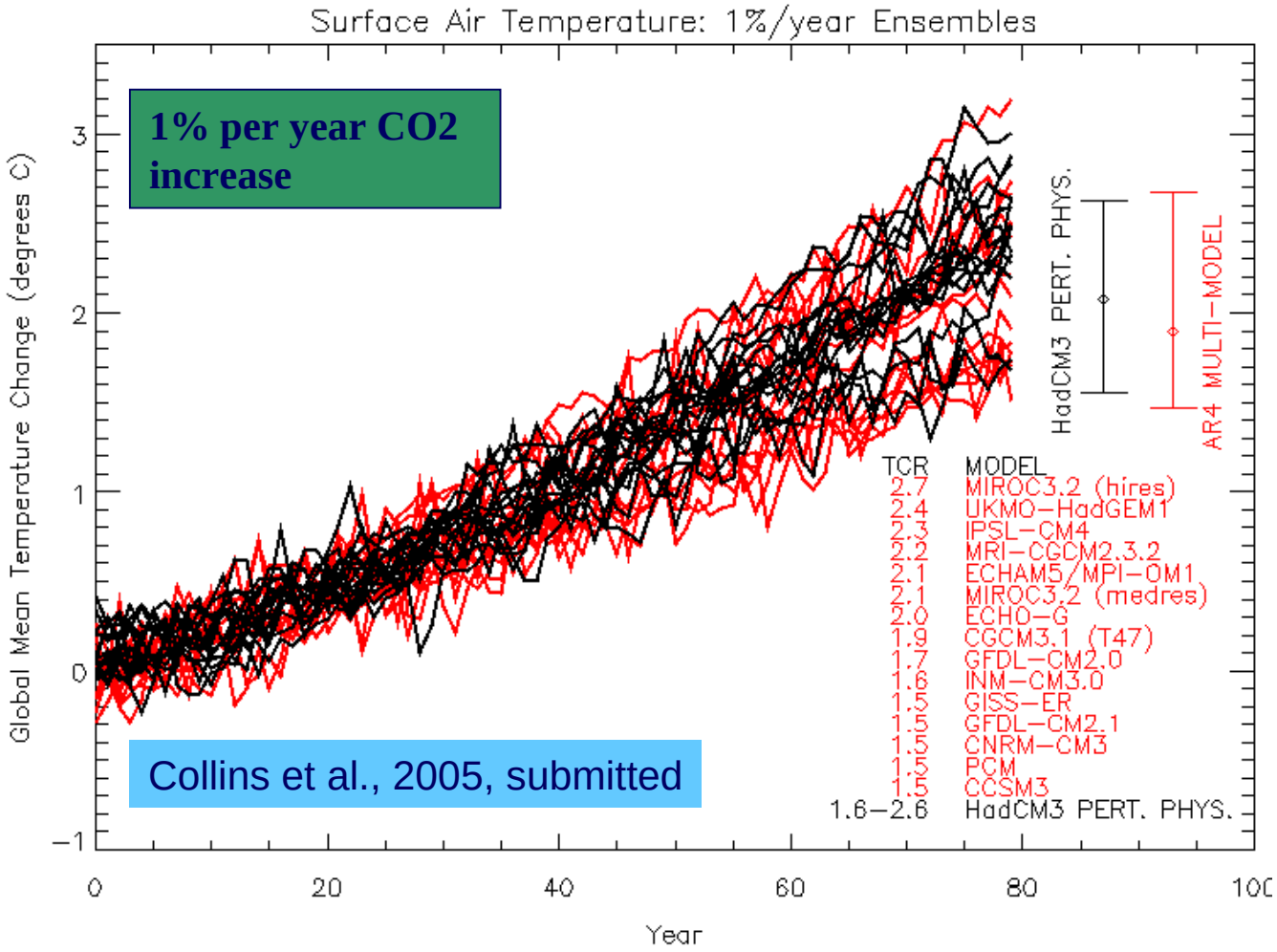


Perturbed parameter approach now extended to multi-parameter ensembles of atmosphere/mixed layer ocean experiments

Murphy et al., 2004; Stainforth et al., 2005; Webb et al., 2005

Progress: Perturbed physics ensembles of the transient response

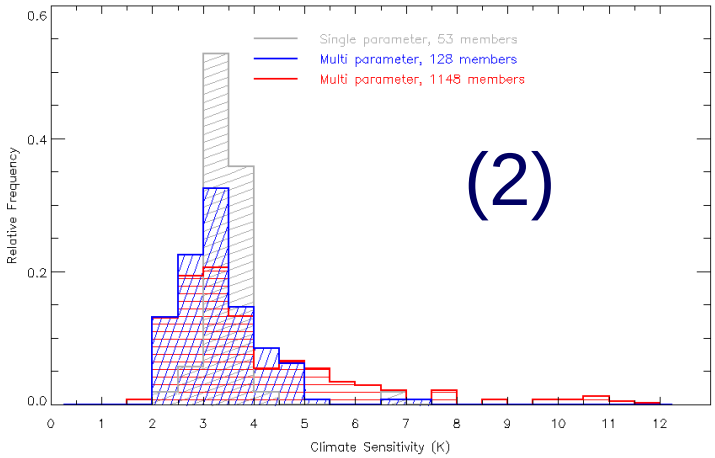
Plans: Comparison with multi-model ensemble simulations (RT2A, IPCC) and with perturbed physics experiments using CNRM and EGMAM models to be produced by RT1



Towards PDFs of regional climate change from perturbed physics ensembles of global models

(1)

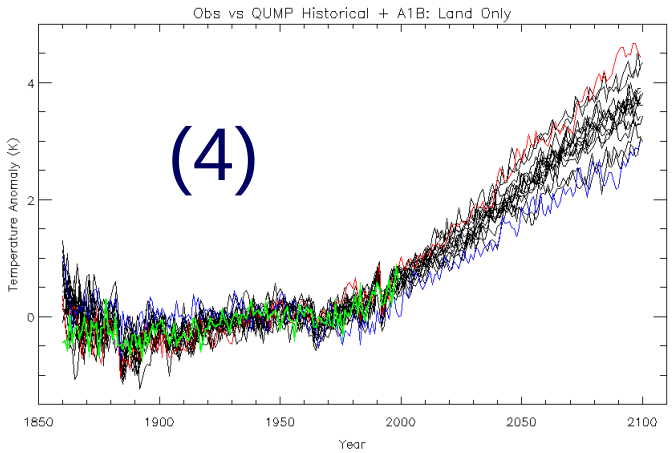
- Take one model (version 3 of the Hadley Centre Atmosphere model coupled to a mixed layer ocean – HadSM3)
- Ask the model experts for ranges on uncertain parameters
- Run an ensemble of equilibrium climate change simulations



(2)

(3)

- Run a smaller ensemble of transient simulations using a subset of perturbed atmospheres coupled to the dynamical HadCM3 ocean



(4)

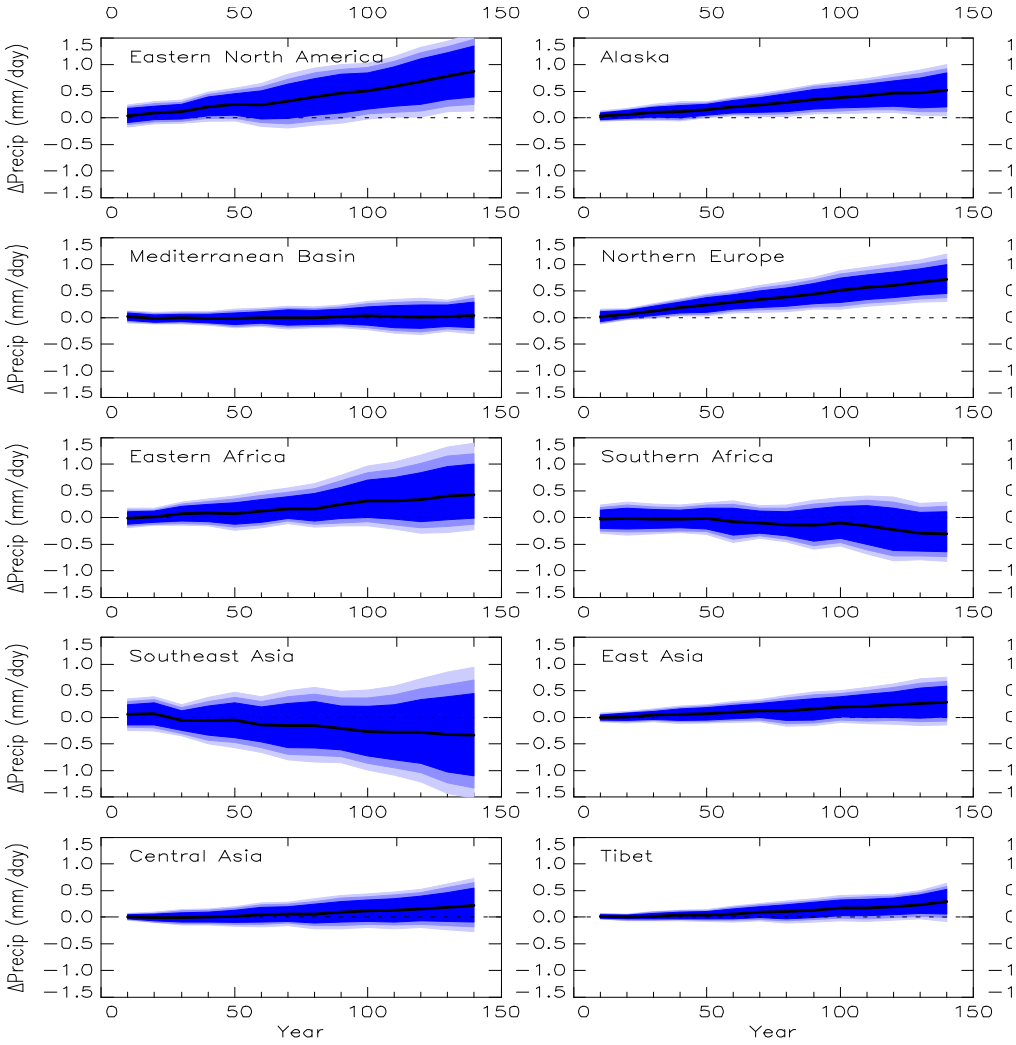
Frequency distributions of transient regional changes

(5)

- Develop scaling relationships between the equilibrium and transient responses and use to infer results of a larger ensemble of transient simulations from the equilibrium ensemble

(6)

- Gives frequency distributions of time dependent changes for regions of choice
- E.g. precip changes over Giorgi regions in DJF



Formal Bayesian framework for probabilistic prediction

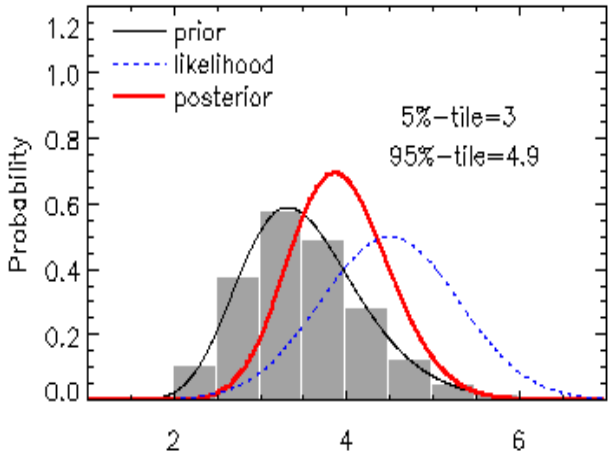
(7)

Take an expert prior for uncertain model parameters

- Construct a prior for climate change variables using a statistical *emulator* to predict GCM results for unsampled regions of parameter space
- Introduce the *discrepancy,* the difference between the observed climate and the best possible model version obtainable by varying parameters. It measures uncertainty arising from structural model deficiencies.
- Estimate (a lower bound for) *discrepancy* by using perturbed physics ensemble results to predict multi-model ensemble results
- Calculate the likelihood and hence produce posterior distributions for future climate variables

$$p(s \mid data) \propto p(s)\, p(data \mid s)$$

posterior = *prior* x *likelihood*



Summary of plans for PDFs of regional climate change from perturbed physics ensembles of global models

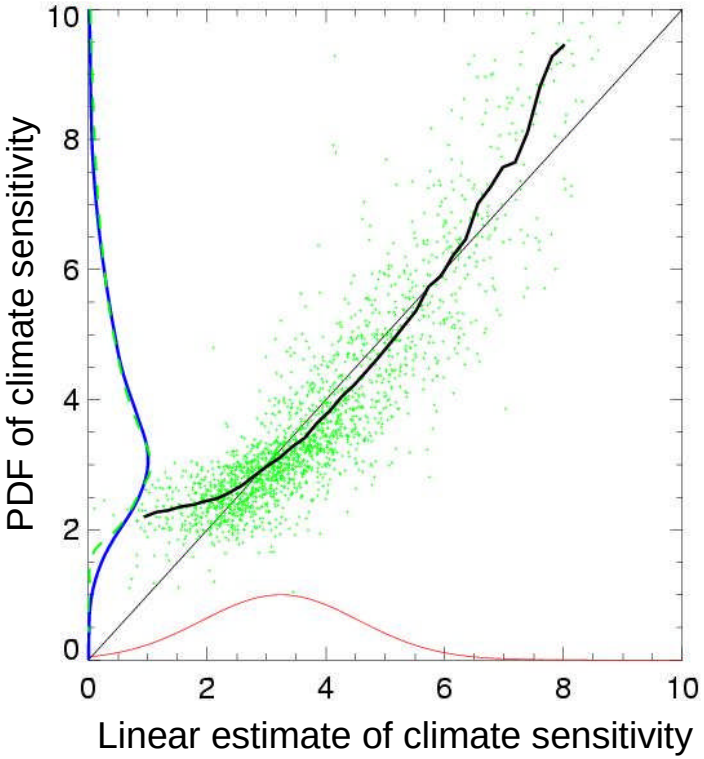
- RT1 will construct a methodology for producing pdfs of regional changes based on perturbed physics ensembles of global models
- We propose an interim product by month 24, consisting of distributions of changes in selected regional variables for Europe, for the A1B forcing scenario, for use by other RTs in testing methodologies for predicting impacts.
- These will account only for surface and atmospheric modelling uncertainties, and will not account for variations in likelihood between different model versions.
- Beyond month 24:
- Hope to use multi-model ensemble results in the construction of likelihood-weighted pdfs, to calibrate the effects of structural model deficiencies.
- Include modelling uncertainties arising from oceanic physical processes, and the terrestrial carbon cycle and atmospheric sulphur cycle, through further ensembles and statistical emulation.

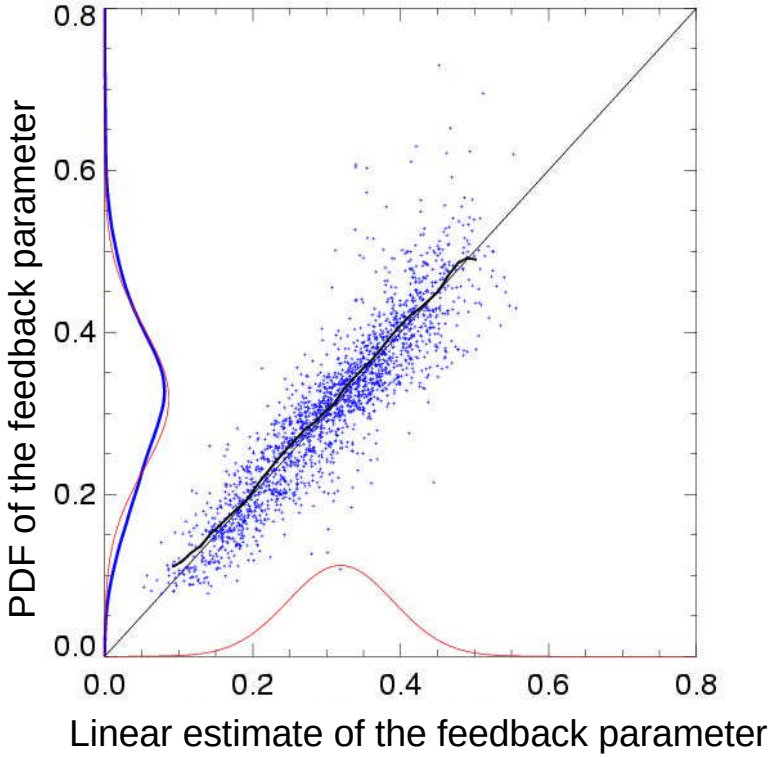
Methods of representing uncertainty (WP 1.2)

Different methods under development, both in ENSEMBLES and worldwide. These are based on different assumptions, e.g.

- The Bayesian method described previously will give results which are dependent on observational constraints and the GCM ensemble distribution. It will be sensitive to choices such as expert-specified parameter ranges, and the method of quantifying model-observation "discrepancy".
- Should be compared against alternative approaches:
- Distributions derived from multi-model ensembles, with or without formal use of observational constraints
- Methods designed to be constrained by observations, and, as far as possible, independent of the underlying ensemble of simulated changes

A methodology for observationally constrained probabilistic predictions (WP 1.2)





Constrains future climate variables using transfer functions between future variables and present day climate observables. Transfer functions developed from the cp.net perturbed parameter ensemble, but results are minimally sensitive to expert choices in the design of the ensemble.

Piani et al., 2005, submitted