Is there a safe GHG stabilization level?
Results from climateprediction.net
NERC Council, 2005

Myles Allen and David Stainforth
Department of Physics, University of Oxford
myles.allen@physics.ox.ac.uk
A potted history of climateprediction.net

1997: Myles Allen, perturbed physics ensemble with MIT 2-D model (Chris Forest et al.)
1999: March: Dermot Dobson introduced MRA to a beta-test version of SETI@home
1999: April: Proposal for “Casino-21” seed-corn funding rejected as utterly unrealistic
1999: July: Andrew Heaps got the Met Office climate model working on a Linux PC
1999: September: Concept presented at World Climate Modelling conference in Hamburg
1999: October: Jim Hansen suggest a web-site so people could sign up: thousands did.
1999: November: David Stainforth joined, half-time, on UGAMP seed-corn funding
2000: January: DAS, with input from Tessella, got the model working under Windows
2000: NERC COAPEC thematic programme agreed to fund DAS for a 3 year pilot study
2000: Jamie Kettleborough and Mat Collins started work on server-side & model devt.
2000: DAS, with James Murphy and David Sexton, Met Office, started perturbations
2000: June: first full-length test on secretarial Windows NT machine at RAL
2000: Summer: Richard Gillis, Tessella, developed first run-management system
2000: DAS & MRA spent much of the year seeking sponsorship from dying dotcoms
2001: Summer: Richard Gault, OU Computing Laboratory, started on e-Science pilot
A potted history of climateprediction.net

2001: December: successful presentation to NERC e-Science panel for launch funding
2002: Bob Spicer, David Frame, Tolu Aina, Beth Grey and Martin Dzbor joined, NERC e-Science
2002: February: Andrew Martin led successful bid to DTI core e-Science for server-side
2002: Summer: Jeremy Walton, NAG, produced “classic” public visualisation interface
2002: September: Steve Bannerman joined to work on server-side development
2002: November: Carl Christensen, SETI & dotcom veteran, joined on core e-Science
2002: December: “Friends and Family” testing begins, with numerous problems
2002: Carl Christensen, Tolu Aina and Jamie Kettleborough extensively rework client and server-side software to improve reliability
2003: David Frame takes over as project coordinator, DAS awarded a NERC Fellowship
2003: March: Sylvia Knight replaces DJF as communications person
2003: April: Beta-testing begins
2003: Friday, September 12th, public launch by Carol Kirkwood, BBC Weather Centre, at the National Museum of Science and Technology
2003: Saturday, September 13th, exceeded the capacity of the Earth Simulator to become the world’s largest climate modelling facility
A potted history of climateprediction.net

2003: October: **Ellie Highwood** at Reading joins
2003: December: first million model years simulated
2004: April: **Stephen Pascoe** joins at RAL to work on results
2004: April: **Hannah Rowlands** takes over as project administrator
2004: May: Thermohaline circulation experiment launched after ‘The Day After Tomorrow’
2004: May: **Neil Massey** joins at ComLab
2004: July: Advanced, interactive visualisation package launched
2004: July: climateprediction.net holds its first Open Day
2004: August: climateprediction.net goes BOINC
2004: December: Schools materials launched
2005: January: First results published in **Nature**
2005: March: climateprediction.net mugs available for purchase
2005: March: 5 million model years simulated
The traditional inter-model-range approach to quantifying uncertainty in climate predictions

(d) Temperature change

- A1FI
- A1B
- A1T
- A2
- B1
- B2
- IS92a (TAR method)

Several models all SRES envelope

Model ensemble all SRES envelope

Bars show the range in 2100 produced by several models
But do inter-model-ranges span responses consistent with observations?

Observed warming

TCR from models and constrained by observations

GHG warming over the 20th Century

Normalised likelihood

Warming at time of CO₂ doubling

CMIP-2 models

No. of models

Decile
But do inter-model-ranges span responses consistent with observations?

Observed warming

TCR from models and constrained by observations

GHG warming over the 20th Century

Normalised likelihood

Warming at time of CO2 doubling

This model was left out
Even bigger discrepancies for high end equilibrium responses
Sources of uncertainty in climate forecasts

Initial condition uncertainty

Boundary condition uncertainty

Response (model) uncertainty
Perturbed Physics Ensembles and Grand Ensembles

- Perturbed physics ensemble: vary parameterisations to find alternative, equally realistic, model versions that respond differently to changing boundary conditions.

- Grand (nested) ensemble explores inter-dependence of the three main sources of uncertainty.
Objectives of climateprediction.net

- Climate research: to improve estimates of uncertainty in climate forecasts by performing the first grand ensemble with a full 3-D climate model.
- E-Science: to develop and demonstrate the potential of public resource distributed computing (PRDC) for large-scale computational modelling tasks.
- Communication: to improve public understanding of the nature of climate modelling and sources of uncertainty in climate predictions.
Climateprediction.net approach

- Invite members of the general public to download a full-resolution 3-D climate model and run it locally on their personal computer.
- Each PC runs a single member of a massive grand ensemble, uploading key diagnostics when simulation is completed.
- Visualization software, educational packages and active user forum maintain interest and facilitate school and undergraduate projects.
Members of the public download and run a full 3-D climate model on their personal computers.
Now running on NERC computers (thanks to Andrew Kaye, Karen Lowther and Ron Price)
Visualization software for school and undergraduate projects
Active user forum to maintain interest
(runs can take two to three months)

ClimatePrediction.Net Community Space
This site is for the current and future users and participants in an existing climate modelling experiment

Forum | Topics | Posts | Last Post
---|---|---|---
**Beta testing experience**
- Unexpected behaviour of your model? Does your model behave differently than expected (e.g. losing times steps, etc.) - let us know... Moderator: David, Emergency 7 | 7 | 39 | Sat May 31, 2003 1:06 pm (old)
- Result and intermediate data upload Any strange behaviour in respect to uploading data or results? Moderator: lad | 4 | 13 | Mon Jun 02, 2003 5:49 pm (model)
- Participation in the experiment Any remarks or suggestions about participating in our experiment? Moderator: David, Emergency 7 | 1 | 4 | Fri May 30, 2003 9:45 am (in帖)

**Technical issues/queries/suggestions**
- Computing efficiency Any concerns about efficiency of modeling or data compressing or something else? Moderator: lad, Emergency 7 | 4 | 22 | Mon Jun 02, 2003 6:15 pm (model)
- Climate model on Linux, commandline option, ... We are planning releases for other systems - e.g. Linux, Mac OS X? Any comments, suggestions, ideas what else... Moderator: lad | 3 | 13 | Wed May 28, 2003 9:20 am (old)
- Setup, debug, network install Comments/Advises about such things as proxies, debugging, software parameters, memory leaks, etc. [shortly, things for geeks] Moderator: lad | 7 | 45 | Mon Jun 02, 2003 10:19 pm (model)
- Other problems when running model Trouble with overheating your computer? Concerned that your laptop is not powerful enough? Advice? Moderator: David, Easy - Enquiries | 3 | 15 | Wed May 28, 2003 12:35 pm (old)

**Climatology/climate science**
- Extreme climate If you think you've got something pretty cool (or hot) in your model, why not telling the others? Moderator: Easy | 2 | 7 | Mon Jun 02, 2003 6:53 pm (model)
- Ozone, global warming Concerned about ozone and global warming in connection with this experiment? Moderator: lad | 2 | 3 | Tue May 27, 2003 10:49 am (old)
- General discussion General forum about discussing climate issues. If anything attracts more attention it can be spawned as a separate topic... | 1 | 5 | Tue May 27, 2003 11:27 am (old)
Uploading results to a network of servers, linked by GRID software for distributed analysis

~100,000 volunteers, 130 countries, ~6M GCM-years
Uploading results to a network of servers, linked by GRID software for distributed analysis.

~100,000 volunteers, 130 countries, ~6M GCM-years

Upload servers
On to the results: initial experiment design

- Using HadSM3 model with thermodynamic ocean
- 15-year calibration, 15-year control, 15-year 2xCO₂
- Up to 10-member IC ensembles to reduce noise and quantify sampling variability
Exploration of parameter space, focusing on identifying non-linear interactions

- Perturbations to 21 parameters
- Three values each, including combinations
- Initial exploration of 6 parameters (clouds and convection)
Time-evolving frequency distribution

Remove models that are unstable in the control.

Few remaining negatively drifting 2xCO₂ model versions are an unrealistic consequence of using a slab ocean.
Not The Day After Tomorrow: why we got some negative sensitivities…
Estimating effective climate sensitivity from short 2xCO₂ runs

4 IC sub-ensembles. Each run with an exponential fit.
Number of runs = 10
Sensitivities from climateprediction.net

Stainforth et al, 2005
Can observations rule out high sensitivities?

Stainforth et al, 2005
Non-linear responses to parameter perturbations: we need these large ensembles

Stainforth et al, 2005
Regional responses: temperature and precipitation

Standard model version

Low sensitivity model

High sensitivity model
Still they come: 47334 simulations passing initial quality control

Courtesy of Ben Sanderson
Are these high sensitivities ruled out by the observed response to Mount Pinatubo?
No: EBM responses to Pinatubo forcing
blue = 0.5K sensitivity, deep red = 20K sensitivity

Frame et al, 2005, also fitting ENSO, background climate and effective heat capacity
Are these high sensitivities ruled out by temperatures in the Last Glacial Maximum?
No: distribution of sensitivities consistent with \( \Delta F = -6.6 \pm 1.5\, \text{W/m}^2 \) & \( \Delta T = -5.5 \pm 0.5\, \text{W/m}^2 \)

Numbers courtesy of Stefan Rahmstorf and Gavin Schmidt
Would these high sensitivities be ruled out if we uploaded more diagnostics?
Not necessarily: Murphy et al, 2004, distribution without prior weighting towards low sensitivities
So how will we constrain S? Searching for predictors in the climateprediction.net ensemble

Piani et al, 2005
Linear prediction works best for the feedback parameter, or $1/S$
Where do we go from here?

- New applications for the world’s largest climate modelling facility.
- Sulphur-cycle release (Highwood et al) under beta-test (feeding into Met Office DEFRA contract).
- Coupled simulations 1950-2050/2100 to follow.
- Local BOINC installation (testing at NERC) for secure intranet environments: provides low-hassle alternative to CONDOR.
- Ultimate goal: making Public Resource Distributed Computing an effective environment for ensemble Earth System Modelling.
New application: probabilistic attribution studies with forecast-resolution models
Using flux adjustment to generate large coupled ensemble without individual spin-ups

Replacing atmosphere in 1950 with more sensitive atmosphere:

Immediate drift with no flux adjustment

Small initial adjustment and slightly faster warming with flux adjustment
Potential Commercial Uses of BOINC Client

- Clinical trial modelling
- Nuclear engineering
- Transport predictions
- Financial hedging models
- Oil reservoir analysis
- Environmental modelling (e.g., river catchments)
- Protein folding simulation
So, did we deliver?

- Climate research: watch this space - need to keep up the pressure on IPCC to take the possibility of extreme high sensitivities seriously.
- E-Science: “the first serious application of distributed computing” (The Economist) and a viable alternative to CONDOR.
- Communication: …
Still some way to go…


Myles Allen, Do it yourself climate prediction, Nature, 401, p.642, October 1999
Output and Performance Measures

Science and Society: Events
- Project representatives at: Adaptation Research Workshop, Stabilisation 2005, Royal Society Exhibition (2005), EGU exhibition, National Science Week, COP-10
- Climateprediction.net Open Day

Science and Society: Publications
Schools Teaching Materials
- Press Coverage of Public Launch, September 2003
  - Articles in more than 20 newspapers worldwide
- Press Coverage of publication in Nature, January 2005
  - Articles in more than 20 newspapers worldwide

Science and Society: Media Activities
Public Launch, September 2003
- TV coverage on BBC News, Newsround, Meridian TV
Publication in Nature, January 2005
- TV coverage on BBC News and Sky News