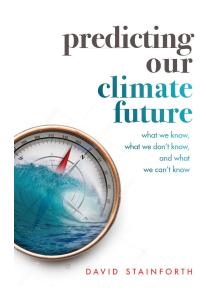
# My Climate Risk Interdisciplinary Learning Group

Prof. David Stainforth, London School of Economics and University of Warwick

**Walker Institute** 

**14th October 2024** 











Phil. Trans. R. Soc. A (2007) 365, 2163-2177 doi:10.1098/rsta.2007.2073 Published online 14 June 2007

PHILOSOPHICAL TRANSACTIONS THE ROYAL A

SOCIETY

Issues in the interpretation of climate model By David A. Stainforth A. Tonord and Many Many BY DAVID A. STAINFORTH LOPEZ AND MARK NEW RICHARD WASHINGTON, ANA LOPEZ AND MARK NEW

gnaai Centre for Cumate Change Kesearch, Environmental Change Institution of Oxford, South Parks Road,

Oxford OX1 20V IIK

Centre for the Environment, Oxford OX1 20V IIK

1 Tyndall Centre for Climate Change Research, Environmental Change Road

1 Tyndall Centre for the Environment University of Orford South Parks

Centre for the Environment University of Orford South Parks

Oxford OX1 3QY, UK
Oxford OX5 Suite 193, 266 Banbury Road
Oxford OX9 7DL

2 Stockholm Environment Institute—Oxford OX9 7DL Oxford OX2 7DL, UK
Oxford OX2 7D Centre for the Analysis of Time-series, Department of Statistics, Bol Columbia House, London School of Economics and Political Scienc Houghton Street, London WC2A 2AE, UK

Houghton Street, London WC2A 2AE, UK

Orford OX1 2OV

4 Centre for the Environment, OX1 2OV

Oxford OX1 2OV

nature climate change

## Tales of future weather PUBLISHED ONLINE: 28 JANUARY 2015 | DOI: 10.1038/NCLIMATE2450 PERSPECTIVE

D.A. Stainforth 6,9,10, E. Vasileiadou 4,8 and L.A. Smith 6,7

W. Hazeleger<sup>1,2,3\*</sup>, B.J.J.M. van den Hurk<sup>1,4</sup>, E. Min<sup>1</sup>, G.J. van Oldenborgh<sup>1</sup>, A.C. Petersen<sup>4,5</sup>

Society is vulnerable to extreme weather events and, by extension, to human impacts on future events. As climate changes weather batterns will change. The search is on for more effective methodologies to aid decision-makers both in mitigation to Society is vulnerable to extreme weather events and, by extension, to human impacts on future events. As climate changes avoid climate change and in adaptation to changes. The traditional approach uses ensembles of climate model simulations, Weather patterns will change. The search is on for more effective methodologies to aid decision-makers both in mitigation to statistical bias correction, downscaling to the spatial and temporal scales relevant to decision-makers, and then translations of the spatial and temporal scales relevant to decision-makers, and then translations of the spatial and temporal scales relevant to decision-makers. avoid climate change and in adaptation to changes. The traditional approach uses ensembles of climate model simulations, into quantities of interest. The veracity of this approach cannot be tested. and it faces in-principle challenges. Alternatively, statistical bias correction, downscaling to the spatial and temporal scales relevant to decision-makers, and then translation models in a bimostation of this approach cannot be tested, and it faces in-principle challenges. Alternatively, into quantities of interest. The veracity of this approach cannot be tested, and it faces in-principle challenges. Alternative of high provide tailored narratives of high provides and the provide tailored narratives of high provides tail numerical weather prediction models in a hypothetical climate setting can provide tailored narratives of P. Industrial Control of the control simulations of high-impact weather in a future climate. This 'tales of future weather' approach will be a simulations. Arguably, it potentially provides complementary. The provides complementary the provides complementary.

# Uncertainty in predictions of the climate response to rising levels of greenhouse gases

D. A. Stainforth <sup>1</sup>, T. Aina <sup>1</sup>, C. Christensen <sup>2</sup>, M. Collins <sup>3</sup>, N. Faull <sup>1</sup>, D. J. Frame <sup>1</sup>, J. A. Kettleborough <sup>1</sup>, S. Knight <sup>1</sup>, A. Martin <sup>2</sup>, J. M. Murphy <sup>3</sup>, C. Piani <sup>1</sup>, D. Sexton <sup>3</sup>, L. A. Smith <sup>5</sup>, R. A. Spicer <sup>6</sup>, A. J. Thorpe <sup>7</sup> & M. B. Allen <sup>1</sup>

<sup>1</sup>Department of Physics, University of Oxford, Parks Road, Oxford OX1 3PU, UK <sup>2</sup>Computing Laboratory, University of Oxford, Parks Road, Oxford OX1 3QD, UK <sup>3</sup>Hadley Centre for Climate Prediction and Research, Met Office, Exeter EX1 3PB, IIK

<sup>4</sup>Rutherford Appleton Laboratory, Chilton, Oxfordshire, OX11 0QX, UK <sup>5</sup>London School of Economics, London WC2A 2AE, UK

<sup>6</sup>Department of Earth Sciences, The Open University, Milton Keynes MK7 6AA, UK

<sup>7</sup>Department of Meteorology, University of Reading, Reading RG6 6BB, UK

The range of possibilities for future climate evolution 1-3 needs to

doubled CO2, to explore the response to changing boundary

Individual simulations are carried out using idle processing capacity on personal computers voluntered by members of the general public". This distributed-computing method<sup>16,10,10</sup> leads to a continually expanding data set of results, requiring us to use a pecified subset of data available at a specific point in time. The analysis presented here uses 2,578 simulations (>100,000 simulated years), chosen to explore combinations of perturbations in six parameters.

The 2,578 simulations contain 2,017 unique simulations (duplicates are used to verify the experimental design—see Methods). Figure Ia shows the grand ensemble frequency distribution of global mean, annual mean, near-surface temperature ( $T_{p^2}$ ) in these 2,017 simulations, as it develops through each phase. Some model versions show substantial drifts in the control phase owing to the use of a simplified ocean (see Supplementary Information). We remove unstable simulations (see Methods) and average over initial-condition ensembles of identical model versions to reduce sampling uncertainty. The frequency distribution of initial-condition—ensemble-mean time series of  $T_{p}$  for the resulting 414 model versions (for which the initial-condition ensembles involve). L148



PHILOSOPHICAL TRANSACTIONS

OF

THE ROYAL

SOCIETY

Phil. Trans. R. Soc. A (2007) 365, 2145–2161 doi:10.1098/rsta.2007.2074 Published online 14 June 2007

## Confidence, uncertainty and decision-support relevance in climate predictions

By D. A. Stainforth  $^{1,3,*},$  M. R. Allen  $^2,$  E. R. Tredger  $^3$  and L. A. Smith  $^3$ 

<sup>1</sup>Tyndall Centre for Climate Change Research, Environmental Change Institute, Centre for the Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, UK
<sup>2</sup>Department of Atmospheric, Oceanic and Planetary Physics, Oxford University, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK
<sup>3</sup>Centre for the Analysis of Time-series, Department of Statistics, Columbia House, London School of Economics and Political Science, Houghton Street, London WC2A 2AE, UK



PERSPECTIV

PUBLISHED ONLINE: 28 JANUARY 2015 | DOI: 10.1038/NCLIMATE2450

#### Tales of future weather

W. Hazeleger<sup>1,2,3</sup>\*, B.J.J.M. van den Hurk<sup>1,4</sup>, E. Min<sup>1</sup>, G.J. van Oldenborgh<sup>1</sup>, A.C. Petersen<sup>4,5</sup>, D.A. Stainforth<sup>6,9,10</sup>. E. Vasileiadou<sup>4,8</sup> and L.A. Smith<sup>6,7</sup>

Society is vulnerable to extreme weather events and, by extension, to human impacts on future events. As climate changes weather patterns will change. The search is on for more effective methodologies to ald decision-makes as obtain initigation to avoid climate change and in adaptation to changes. The traditional approach uses ensembles of climate model simulations, statistical bias correction, downscing to the spatial and temporal scales relevant to decision-makers, and then transition into quantities of interest. The veracity of this approach cannot be tested, and it faces in-principle challenges. Alternatively, numerical weather prediction models in a hypothetical climate setting can provide tailored narratives of high-responsition simulations of high-impact weather in a future climate. This 'tales of future weather' approach will aid in the interpretation of provides complementary, more realistic and more physically consistent obscures of what future weather in micht look like.



Phil. Trans. R. Soc. A (2007) **365**, 2163–2177 doi:10.1098/rsta.2007.2073 Published online 14 June 2007

## Issues in the interpretation of climate model ensembles to inform decisions

By David A. Stainforth<sup>1,3,\*</sup>, Thomas E. Downing<sup>2</sup>, Richard Washington<sup>4</sup>, Ana Lopez<sup>1</sup> and Mark New<sup>4</sup>

<sup>1</sup>Tyndall Centre for Climate Change Research, Environmental Change Institute, Centre for the Environment, University of Oxford, South Parks Road, Oxford OX1 3OY, UK

<sup>2</sup>Stockholm Environment Institute—Oxford, Suite 193, 266 Banbury Road, Oxford OX2 7DL, UK

<sup>3</sup>Centre for the Analysis of Time-series, Department of Statistics, B613, Columbia House, London School of Economics and Political Science, Houghton Street, London WC2A 2AE, UK

<sup>4</sup>Centre for the Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, UK

#### letters to nature

#### Uncertainty in predictions of the climate response to rising levels of greenhouse gases

D. A. Stainforth', T. Aina', C. Christensen', M. Collins', N. Faull', D. J. Frame', J. A. Kettleborough', S. Knight', A. Martin', J. M. Murphy', C. Plani', D. Sexton', L. A. Smith', R. A. Spicer', A. J. Thorpe' & M. R. Allen'

pating Laboratory, University of Oxford, Parks Rand, Oxford OX1 3QD, UK ley Centre for Climate Profiction and Research, Met Office, Exter EX1 3PB,

ra Apparate Laboratory, Collison, Coponiumer, OKT1 OGSL, UK School of Economics, Landon WC2A 2AE, UK sent of Earth Sciences, The Open University, Milton Keynes MK7 6AA,

doubled CO2, to explore the response to changing boundary Individual simulations are carried out using idle processing capacity on personal computers volunteered by members of the general public.<sup>17</sup>. This distributed-computing method<sup>16,18,18</sup> leads to continually expanding data set of results, requiring us to use a years), chosen to explore combinations of perturbations in s

cates are used to verify the experimental design—see Methods). Figure Ia shows the grand ensemble frequency distribution of global regure 1a snows the grand ensemble frequency distribution of global mean, annual mean, near-surface temperature  $(T_g)$  in these 2,017 simulations, as it develops through each phase. Some model versions show substantial drifts in the control phase owing to the use of a simplified ocean (see Supplementary Information). We remove unstable simulations (see Methods) and average over initial-condition ensembles of identical model versions to reduce Chepurboset of Metocockgy, University of Reading, Reading Ros 688, UK

The range of possibilities for future climate evolution<sup>1-3</sup> needs to

"Story of the range of possibilities for future climate evolution of seeds to

"Story of the story of the seeds of the seed



tory, Chilton, Oxfordshire, OX11 0QX, UK

PHILOSOPHICAL TRANSACTIONS THE ROYAL

Phil. Trans. R. Soc. A (2007) 365, 2145-2161 doi:10.1098/rsta.2007.2074 Published online 14 June 2007

#### Confidence, uncertainty and decision-support relevance in climate predictions

By D. A. Stainforth<sup>1,3,\*</sup>, M. R. Allen<sup>2</sup>, E. R. Tredger<sup>3</sup> AND L. A. SMITH

<sup>1</sup>Tyndall Centre for Climate Change Research, Environmental Change Institute, Centre for the Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, UK

<sup>2</sup>Department of Atmospheric, Oceanic and Planetary Physics, Oxford University, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK <sup>3</sup>Centre for the Analysis of Time-series, Department of Statistics, Columbia House, London School of Economics and Political Science, Houghton Street, London WC2A 2AE, UK

climate change

PERSPECTIVE PUBLISHED ONLINE: 28 JANUARY 2015 | DOI: 10.1038/NCLIMATE

#### Tales of future weather

W. Hazeleger<sup>1,2,3\*</sup>, B.J.J.M. van den Hurk<sup>1,4</sup>, E. Min<sup>1</sup>, G.J. van Oldenborgh<sup>1</sup>, A.C. Petersen<sup>4,5</sup> D.A. Stainforth<sup>6,9,10</sup>, E. Vasileiadou<sup>4,8</sup> and L.A. Smith<sup>6,7</sup>

Society is vulnerable to extreme weather events and, by extension, to human impacts on future events. As climate changes weather patterns will change. The search is on for more effective methodologies to aid decision-makers both in mitigation to avoid climate change and in adaptation to changes. The traditional approach uses ensembles of climate model simulations, statistical bias correction, downscaling to the spatial and temporal scales relevant to decision-makers, and then translation into quantities of interest. The veracity of this approach cannot be tested, and it faces in-principle challenges. Alternatively, numerical weather prediction models in a hypothetical climate setting can provide tailored narratives of high-resolut simulations of high-impact weather in a future climate. This 'tales of future weather' approach will aid in the interpretation of lower-resolution simulations. Arguably, it potentially provides complementary, more realistic and more physically consi nictures of what future weather might look like



Phil. Trans. R. Soc. A (2007) 365, 2163-2177 doi:10.1098/rsta.2007.2073 Published online 14 June 2007

#### Issues in the interpretation of climate model ensembles to inform decisions

By David A. Stainforth<sup>1,3,\*</sup>, Thomas E. Downing<sup>2</sup>. RICHARD WASHINGTON<sup>4</sup>, ANA LOPEZ<sup>1</sup> AND MARK NEW<sup>4</sup>

Tyndall Centre for Climate Change Research, Environmental Change Institute, Centre for the Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, UK

<sup>2</sup>Stockholm Environment Institute—Oxford, Suite 193, 266 Banbury Road, Oxford OX2 7DL, UK

<sup>3</sup>Centre for the Analysis of Time-series, Department of Statistics, B613, Columbia House, London School of Economics and Political Science, Houghton Street, London WC2A 2AE, UK

<sup>4</sup>Centre for the Environment, University of Oxford, South Parks Road. Oxford OX1 3OY, UK

IOP Publishing

Environ, Res. Lett. 13 (2018) 074005

https://doi.org/10.1088/1748-9326/aabcdd

#### **Environmental Research Letters**

Gosling5, Neha Mittal1 and David Stainforth2,6,7



#### LETTER

OPEN ACCESS

Building narratives to characterise uncertainty in regional climate change through expert elicitation

Suraie Dessai<sup>1,8</sup>, Aiav Bhave<sup>1,2</sup>, Cathryn Birch<sup>1,3</sup>, Declan Conway<sup>2</sup>, Luis Garcia-Carreras<sup>4</sup>, John Paul

22 December 2017

29 March 2018

10 April 2018 PUBLISHED 26 June 2018

Original content from

this work may be used under the terms of the

Attribution 3.0 licence

Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science, London, WC2A 2AE, United Kingdom

Met Office, Exeter, United Kingdom School of Earth and Environmental Sciences, The University of Manchester, Manchester, M13 9PL, United Kingdom

School of Mathematics, University of Leeds, Leeds, LS2 9JT, United Kingdom

Department of Physics, University of Warwick, Coventry, United Kingdom Centre for the Analysis of Time Series, London School of Economics and Political Science, London, United Kingdom

Author to whom any correspondence should be addressed.

School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, United Kingdom

E-mail: s dossai@loods ac ul



#### **@AGU** PUBLICATIONS



#### Water Resources Research

#### RESEARCH ARTICLE

10.1002/2017WR020970

#### Special Section:

Engagement, Communication, and Decision-Making Under Uncertainty

#### **Key Points:**

· An iterative approach combining qualitative and quantitative methods is used to assess robustness of

#### Water Resource Planning Under Future Climate and Socioeconomic Uncertainty in the Cauvery River Basin in Karnataka, India

Ajay Gajanan Bhave<sup>1,2</sup> O, Declan Conway<sup>1</sup>, Suraje Dessai<sup>2</sup> O, and David A. Stainforth<sup>1,3,4</sup> O

<sup>1</sup>London School of Economics and Political Science, Grantham Research Institute on Climate Change and the Environment, London, UK, <sup>2</sup>Sustainability Research Institute and ESRC Centre for Climate Change Economics and Policy, School of Earth and Environment, University of Leeds, Leeds, UK, 3London School of Economics and Political Science, Centre for the Analysis of Time Series, London, UK, <sup>4</sup>Department of Physics, University of Warwick, Coventry, UK

#### letters to nature

#### Uncertainty in predictions of the climate response to rising levels of greenhouse gases

D. A. Stainforth<sup>1</sup>, T. Aina<sup>1</sup>, C. Christensen<sup>2</sup>, M. Dollins<sup>2</sup>, N. Faull<sup>1</sup>, D. J. Frame<sup>1</sup>, J. A. Kettieborough<sup>1</sup>, S. Knight<sup>1</sup>, A. Martin<sup>2</sup>, J. M. Murphy<sup>3</sup>, C. Pizan<sup>1</sup>, D. Sexton<sup>3</sup>, L. A. Smith<sup>3</sup>, R. A. Spicor<sup>3</sup>, A. J. Thorpe<sup>3</sup> & M. R. Allen<sup>3</sup>

doubled CO2, to explore the response to changing boundary conditions.

Individual simulations are carried out using idle processin capacity on personal computers volunteered by members of the general public.19. This distributed-computing method\*\*1.38.19 leads to a continually expanding data set of results, requiring us to use a specified subset of data available at a specific point in time. The analysis presented here uses 2.578 simulations (>100,000 simulated

pair (), & Destrit (, k, now...)

1. A final

"Growned of Privac, Unioning of Option, Delan And Option (DD VE); US

"Growned of Privac, Unioning of Option, Delan And Option (DD VE); US

"Growned Privac, Delan Option, Delan Option, DEL VE); US

"Growned And Privace, Union, Option, Option, OCH VE); US

"Growned And Privace, Union, Option, Delan Option, OCH VE); US

"Growned And Privace, Union, Option, OCH VE); US

"Growned And Privace, Union, Option, OCH VE); US

"Growned And Privace, Union, Octoor, US

"Growned And Privace, Union, Octoor, US

"Growned And Privace, Union, OCH VE); US

"Growned And Privace, Union, Octoor, US

"Growned And Privace, Union, Octoor, US

"Growned And Privace, Union, OCH VE); US

"Growned And Privace, Union, Octoor, US

"Growned And Privace, Union, Un sampling uncertainty. The frequency distribution of initial-con-dition-ensemble-mean time series of T<sub>R</sub> for the resulting 414 mode The range of possibilities for future climate evolution on needs to versions (for which the initial-condition ensembles involve 1.148



#### PHILOSOPHICAL TRANSACTIONS THE ROYAL

Phil. Trans. R. Soc. A (2007) 365, 2145-2161 doi:10.1098/rsta.2007.2074 Published online 14 June 2007

#### Confidence, uncertainty and decision-support relevance in climate predictions

By D. A. Stainforth<sup>1,3,\*</sup>, M. R. Allen<sup>2</sup>, E. R. Tredger<sup>3</sup> AND L. A. SMITH

<sup>1</sup>Tyndall Centre for Climate Change Research, Environmental Change Institute, Centre for the Environment, University of Oxford, South Parks Road, Oxford OX1 3OY, UK

<sup>2</sup>Department of Atmospheric, Oceanic and Planetary Physics, Oxford University, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK <sup>3</sup>Centre for the Analysis of Time-series, Department of Statistics, Columbia House, London School of Economics and Political Science, Houghton Street, London WC2A 2AE, UK

climate change

**PERSPECTIVE** PUBLISHED ONLINE: 28 JANUARY 2015 | DOI: 10.1038/NCLIMATES

#### Tales of future weather

W. Hazeleger<sup>1,2,3\*</sup>, B.J.J.M. van den Hurk<sup>1,4</sup>, E. Min<sup>1</sup>, G.J. van Oldenborgh<sup>1</sup>, A.C. Petersen<sup>4,5</sup>, D.A. Stainforth<sup>6,9,10</sup>, E. Vasileiadou<sup>4,8</sup> and L.A. Smith<sup>6,7</sup>

Society is vulnerable to extreme weather events and, by extension, to human impacts on future events. As climate change: weather patterns will change. The search is on for more effective methodogies to aid decision-makers both in mitigation to avoid climate change and in adaptation to changes. The traditional approach uses ensembles of climate model simulations. statistical bias correction, downscaling to the spatial and temporal scales relevant to decision-makers, and then translation into quantities of interest. The veracity of this approach cannot be tested, and it faces in-principle challenges. Alternatively numerical weather prediction models in a hypothetical climate setting can provide tailored narratives of high-resolution simulations of high-impact weather in a future climate. This 'tales of future weather' approach will aid in the interpretation o lower-resolution simulations. Arguably, it potentially provides complementary, more realistic and more physically consistent pictures of what future weather might look like.



Phil. Trans. R. Soc. A (2007) 365, 2163-2177 doi:10.1098/rsta.2007.2073 Published online 14 June 2007

#### Issues in the interpretation of climate model ensembles to inform decisions

By David A. Stainforth<sup>1,3,\*</sup>, Thomas E. Downing<sup>2</sup>, RICHARD WASHINGTON<sup>4</sup>, ANA LOPEZ<sup>1</sup> AND MARK NEW<sup>4</sup>

<sup>1</sup>Tyndall Centre for Climate Change Research, Environmental Change Institute, Centre for the Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, UK

<sup>2</sup>Stockholm Environment Institute—Oxford, Suite 193, 266 Banbury Road. Oxford OX2 7DL, UK

<sup>3</sup>Centre for the Analysis of Time-series, Department of Statistics, B613, Columbia House, London School of Economics and Political Science, Houghton Street, London WC2A 2AE, UK

<sup>4</sup>Centre for the Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, UK

IOP Publishing

Environ. Res. Lett. 13 (2018) 074005

https://doi.org/10.1088/1748-9326/aabcdd

#### **Environmental Research Letters**



Building narratives to characterise uncertainty in regional climate change through expert elicitation

Suraje Dessai<sup>1,8</sup>©, Ajay Bhave<sup>1,2</sup>, Cathryn Birch<sup>1,3</sup>, Declan Conway<sup>2</sup>, Luis Garcia-Carreras<sup>4</sup>, John Paul Gosling5, Neha Mittal1 and David Stainforth2,6,7

acusco 29 March 2018

School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, United Kingdom Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science, London,

ACCEPTED FOR PUBLICATION 10 April 2018

- Mot Office Evotor United Kingdom School of Earth and Environmental Sciences. The University of Manchester, Manchester, M13 9PL, United Kingdom
- School of Mathematics, University of Leeds, Leeds, LS2 9TT, United Kingdom Department of Physics, University of Warwick, Coventry, United Kingdom Original content from Centre for the Analysis of Time Series, London School of Economics and Political Science, London, United Kingdom

8 Author to whom any correspondence should be addressed.

WC2A 2AE, United Kingdom



#### **@AGU** PUBLICATIONS

#### Water Resources Research

#### 10.1002/2017WR020970

Special Section: Engagement, Communication

and Decision-Making Under Uncertainty

· An iterative approach combining qualitative and quantitative methods is used to assess robustness of

RESEARCH ARTICLE Water Resource Planning Under Future Climate and Socioeconomic Uncertainty in the Cauvery River Basin in Karnataka, India

Ajay Gajanan Bhave 1.2 Declan Conway 1, Suraje Dessai 2 Dessai 4 David A. Stainforth 1.3.4 Declan Conway 1

London School of Economics and Political Science, Grantham Research Institute on Climate Change and the Environment London LIK 25 istainability Research Institute and ESRC Centre for Climate Change Economics and Policy School of Earth and Environment, University of Leeds, Leeds, UK. 3 London School of Economics and Political Science. Centre for the Analysis of Time Series, London, UK, <sup>4</sup>Department of Physics, University of Warwick, Coventry, UK



predicting our climate future

# Distribution of Climate Sensitivity from a perturbed-parameter ensemble

#### letters to nature

# Uncertainty in predictions of the climate response to rising levels of greenhouse gases

D. A. Stainforth<sup>1</sup>, T. Aina<sup>1</sup>, C. Christensen<sup>2</sup>, M. Collins<sup>3</sup>, N. Faull<sup>1</sup>, D. J. Frame<sup>1</sup>, J. A. Kettleborough<sup>2</sup>, S. Knight<sup>1</sup>, A. Martin<sup>2</sup>, J. M. Murphy<sup>3</sup>, C. Plani<sup>1</sup>, D. Sexton<sup>3</sup>, L. A. Smith<sup>3</sup>, R. A. Spicer<sup>6</sup>, A. J. Thorpe<sup>7</sup> & M. R. Allen<sup>1</sup>

<sup>1</sup>Department of Physics, University of Oxford, Parks Road, Oxford OXI 3PU, UK

<sup>2</sup>Hadley Centre for Climate Prediction and Research, Met Office, Exeter EXI 3PB, UK

<sup>8</sup>Radley Centre for Climate Prediction and Research, Met Office, Exeter EXI 3PB, UK

<sup>8</sup>Ratherford A Anoletum Laboratory, Chillum, Oxfordshire, OXI 10 OX, UK

Rutnerford Appseton Laboratory, Cutton, Oxforismire, OX11 0QA, UK

\*London School of Economics, London WC2A 2AE, UK

\*Department of Earth Sciences, The Open University, Milton Keynes MK7 6AA,

<sup>7</sup>Department of Meteorology, University of Reading, Reading RG6 6BB, UK

The range of possibilities for future climate evolution 1-3 needs to

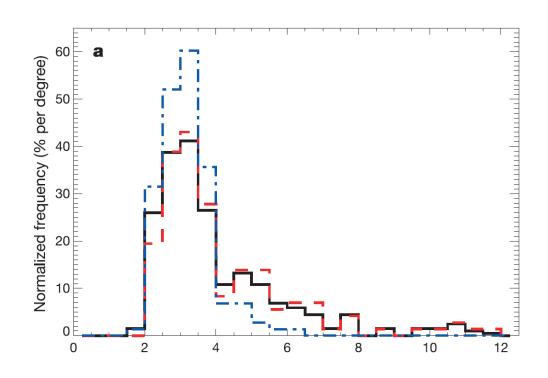
doubled CO2, to explore the response to changing boundary

Individual simulations are carried out using idle processing capacity on personal computers volunteered by members of the general public." This distributed-computing method." Assist leads to a continually expanding data set of results, requiring us to use a specified subset of data available at a specific point in time. The analysis presented here uses 2,578 simulations (>100,000 simulated years), chosen to explore combinations of perturbations in six

The 2,578 simulations contain 2,017 unique simulations (duplicates are used to verify the experimental design—see Methods). Figure I asbows the gand ensemble frequency distribution of global mean, annual mean, near-surface temperature (T<sub>2</sub>) in these 2,017 simulations, as it develops through each phase. Some model oversions show substantial drifts in the control phase woing to the use of a simplified occan (see Supplementary Information). We remove mustable simulations (see Methods) and average over initial-condition ensembles of identical model versions for reduce sampling uncertainty. The frequency distribution of initial-condition-ensemble-mean time series of T<sub>2</sub> for the resulting 414 model versions (for which the initial-condition ensembles involved. 1488

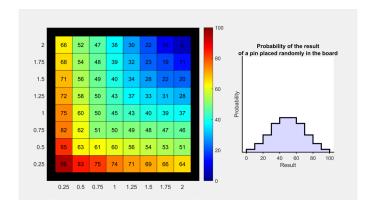
"The shape of the distribution is determined by the parameters selected for perturbation and the perturbed values chosen, which were relatively arbitrary."

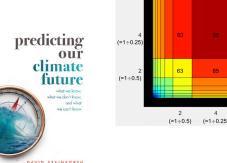
"In our case even the physical interpretation of many of these parameters is ambiguous."

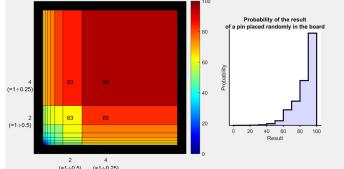


## Challenge: How can we relate models and reality?

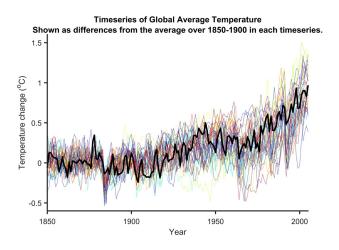
- A probability distribution across different models is fundamentally arbitrary because we have no metric for the space of possible models.
- Even a distribution across a perturbed parameter ensemble is arbitrary because the parameter space is not defined.

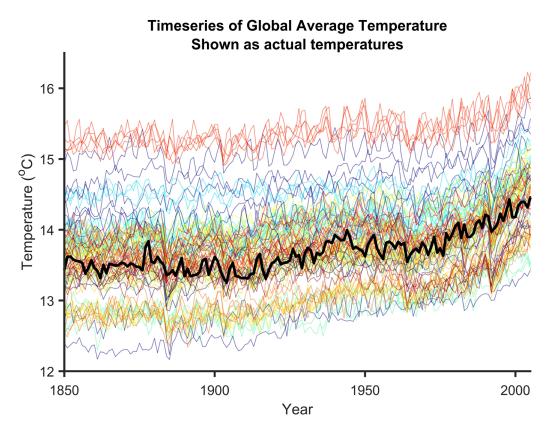




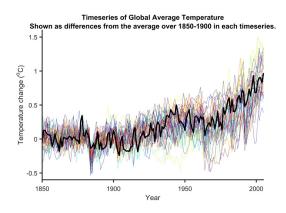


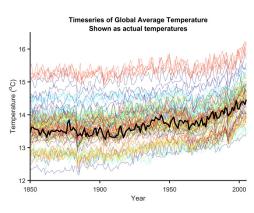
# All models are substantially different to reality.

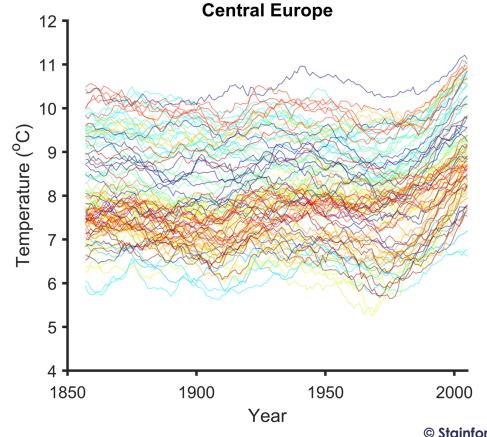




# All models are substantially different to reality.







# Chasing better models is unlikely to be fruitful at the moment.

- We don't know what we're aiming for.
   We haven't studied the question: when would a model be good enough to answer the questions we're asking.
- We have no means of forecast verification so we rely on model fidelity.

# Non-discountable Envelopes Lower Bounds on the Maximum Range of Uncertainty

#### PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY

Phil. Trans. R. Soc. A (2007) 365, 2163–2177 doi:10.1098/rsta.2007.2073 Published online 14 June 2007

#### Issues in the interpretation of climate model ensembles to inform decisions

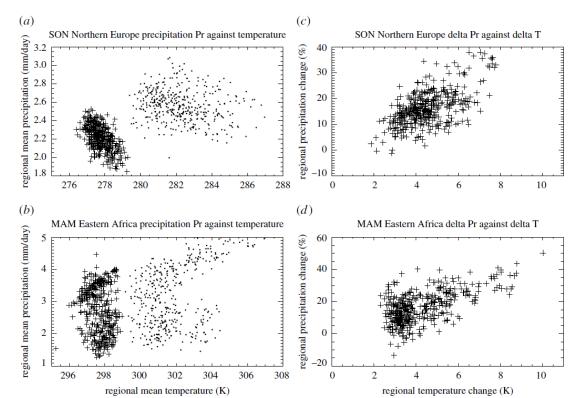
By David A. Stainforth<sup>1,3,\*</sup>, Thomas E. Downing<sup>2</sup>, Richard Washington<sup>4</sup>, Ana Lopez<sup>1</sup> and Mark New<sup>4</sup>

<sup>1</sup>Tyndall Centre for Climate Change Research, Environmental Change Institute, Centre for the Environment, University of Oxford, South Parks Road, Oxford OXI 30Y, UK

<sup>2</sup>Stockholm Environment Institute—Oxford, Suite 193, 266 Banbury Road, Oxford OX2 7DL, UK

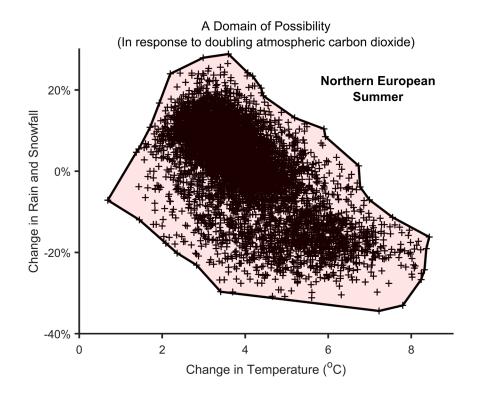
<sup>3</sup>Centre for the Analysis of Time-series, Department of Statistics, B613, Columbia House, London School of Economics and Political Science, Houghton Street, London WC2A 2AE, UK

<sup>4</sup>Centre for the Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, UK



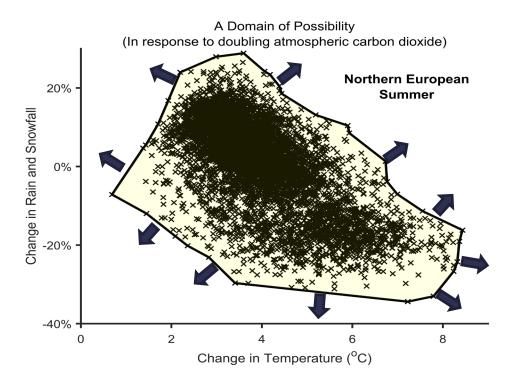
# Non-discountable Envelopes Lower Bounds on the Maximum Range of Uncertainty





# Non-discountable Envelopes Lower Bounds on the Maximum Range of Uncertainty





# Storylines as a route to identifying possible futures

nature climate change

PUBLISHED ONLINE: 28 JANUARY 2015 | DOI: 10.1038/NCLIMATE2450

#### Tales of future weather

W. Hazeleger<sup>1,2,3\*</sup>, B.J.J.M. van den Hurk<sup>1,4</sup>, E. Min<sup>1</sup>, G.J. van Oldenborgh<sup>1</sup>, A.C. Petersen<sup>4,5</sup>, D.A. Stainforth<sup>6,9,10</sup>, E. Vasileiadou<sup>4,8</sup> and L.A. Smith<sup>6,7</sup>

Society is vulnerable to extreme weather events and, by extension, to human impacts on future events. As climate changes weather patterns will change. The search is on for more effective methodologies to aid decision-makers both in mitigation to avoid climate change and in adaptation to changes. The traditional approach uses ensembles of climate model simulations, statistical bias correction, downscaling to the spatial and temporal scales relevant to decision-makers, and then translation into quantities of interest. The veracity of this approach cannot be tested, and it faces in-principle challenges. Alternatively, numerical weather prediction models in a hypothetical climate setting can provide tailored narratives of high-resolution simulations of high-impact weather in a future climate. This 'tales of future weather' approach will aid in the interpretation of lower-resolution simulations. Arguably, it potentially provides complementary, more realistic and more physically consistent pictures of what future weather might look like.

How might one construct Tales to inform adaptation decisions 14 and mitigation policy? The use of global high-resolution atmosphere models that resolve the synoptic scales (model gridspacing is currently about 10 km and is expected to improve in the near term) — the reliability of which are well understood within the frame of numerical weather prediction — allows a more physically coherent expression of what weather in an altered climate could feel and look like<sup>25</sup>. It is possible to provide a limited set of future weather scenarios that explore a range of plausible realizations of future climate. The scenarios are imposed onto the boundary conditions (sea surface temperatures, atmospheric composition, land use and so on) of a high-resolution model. The boundary conditions may be obtained from traditional coupled climate model simulations of future climate, but they could equally well be inspired by other sources, including palaeoclimate data, sensitivity experiments with coupled models, archives of past meteorological analyses and forecasts, or even simple constructions of physically credible possibilities. The synoptic patterns related to the 2003 heat wave or the 2013 floods in Europe, for instance, could be simulated repeatedly using expert-elicited patterns of changes in sea surface temperatures and radiative forcing representative of a warmer world. In this way a wider range of plausible realizations of an alternative climate can be considered than with traditional coupled climate model experiments.

# Storylines as a route to identifying possible futures

nature climate change PERSPECTIVE Climate change PUBLISHED ONLINE 28 ANNUARY 2015 [DOI: 10.1018/NICLIMATEAS

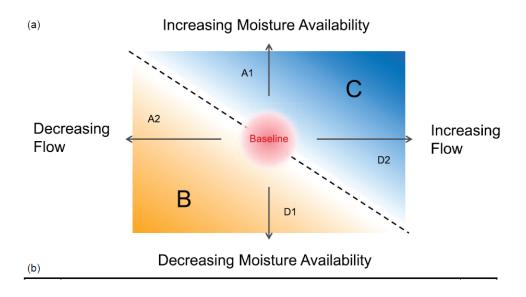
#### Tales of future weather

W. Hazeleger<sup>1,2,3</sup>\*, B.J.J.M. van den Hurk<sup>1,4</sup>, E. Min<sup>1</sup>, G.J. van Oldenborgh<sup>1</sup>, A.C. Petersen<sup>4,5</sup>, D.A. Stainforth<sup>6,9,10</sup>, E. Vasileiadou<sup>4,8</sup> and L.A. Smith<sup>6,7</sup>

Society is unleasable to extreme weather events and, by extension, to human impacts on future events. As climate changes weather patterns will change. The search in our owner effective methodologies to an decision-maker both in military in the statistical basis correction, downscripting to the apartial and temporal scales relevant to decision-makers, and then transitions in aquantities of interest. The vernetty of this proposal cannot be stated, and it faces in-principle challenges. Attentions to the control of the control of

How might one construct Tales to inform adaptation decisions and mitigation policy? The use of global high-resolution atmosphere models that resolve the synoptic scales (model grid-spacing is currently about 10 km and is expected to improve in the near term) — the reliability of which are well understood within the frame of numerical weather prediction — allows a more physically coherent expression of what weather in an altered climate could feel and look like 25. It is possible to provide a limited set of future weather scenarios that explore a range of plausible realizations of future climate. The scenarios are imposed onto the boundary conditions (sea surface temperatures, atmospheric composition, land use and so on) of a high-resolution model. The boundary conditions may be obtained from traditional coupled climate model simulations of future climate, but they could equally well be inspired by other sources, including palaeoclimate data, sensitivity experiments with coupled models, archives of past meteorological analyses and forecasts, or even simple constructions of physically credible possibilities. The synoptic patterns related to the 2003 heat wave or the 2013 floods in Europe, for instance, could be simulated repeatedly using expertelicited patterns of changes in sea surface temperatures and radiative forcing representative of a warmer world. In this way a wider range of plausible realizations of an alternative climate can be considered than with traditional coupled climate model experiments.

# Storylines /Narratives Use imagination constrained by physical understanding to provide a range of credible futures





### **Questions / Debate**

d.a.stainforth@lse.ac.uk

climateconfidence.net

@climatehat LinkedIn

Please email me if you would like to receive a discount code to get 30% off my book from oup.com

# predicting our climate future

what we know, what we don't know, and what we can't know

DAVID STAINFORTH