

PAPER • OPEN ACCESS

## Analysis of aridity characteristics in Europe in the last millennium according to calculations with climatic models

To cite this article: N A Mirsaeva and A V Eliseev 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **386** 012055

View the [article online](#) for updates and enhancements.

### You may also like

- [Eta Carinae: The Dissipating Occulter Is an Extended Structure](#)  
Theodore R. Gull, Henrik Hartman, Mairan Teodoro et al.
- [The Little Cub: Discovery of an Extremely Metal-poor Star-forming Galaxy in the Local Universe](#)  
Tiffany Hsyu, Ryan J. Cooke, J. Xavier Prochaska et al.
- [MOJAVE. XIII. PARSEC-SCALE AGN JET KINEMATICS ANALYSIS BASED ON 19 YEARS OF VLBA OBSERVATIONS AT 15 GHz](#)  
M. L. Lister, M. F. Aller, H. D. Aller et al.



**ECS**  
The  
Electrochemical  
Society  
Advancing solid state &  
electrochemical science & technology

**DISCOVER**  
how sustainability  
intersects with  
electrochemistry & solid  
state science research

# Analysis of aridity characteristics in Europe in the last millennium according to calculations with climatic models

**N A Mirsaeva<sup>1</sup> and A V Eliseev<sup>1,2,3</sup>**

<sup>1</sup> Institute of Environmental Sciences, Kazan Federal University, 18 Kremlyovskaya Street, Kazan, Russia

<sup>2</sup> Faculty of Physics, Lomonosov Moscow State University, 1-2 Leninskie Gory, Moscow, Russia

<sup>3</sup> A M Obukhov Institute of Atmospheric Physics RAS, 3 Pyzhevsky, Moscow, Russia

**Abstract.** Spatio-temporal distributions of aridity characteristics in Europe based on results of CMIP5 experiments are considered. According to calculations with a model, MPI-ESM-P, climate cooling in the Little Ice Age is characterized by a more humid climate in northern Europe compared with that in the pre-industrial period, although the changes are statistically insignificant. For the medieval climatic optimum, the changes in the climate humidification mode from the pre-industrial period are statistically insignificant. According to calculations with the IAP RAS CM model, cooling in the Little Ice Age is characterized by a more humid climate in the North-Eastern Atlantic compared with that in the pre-industrial period, and the changes are statistically significant.

## 1. Introduction

The World Economic Forum (WEF) published lists of global risks for 2017 [1]. The first position in the five most probable global risks was taken by hazardous weather events, including droughts. Drought, as a dangerous natural phenomenon, is determined primarily by meteorological factors, despite the variety of other factors contributing to its occurrence.

Recently, interest in the spatio-temporal characteristics of aridity has grown significantly. First of all, it is due to the negative impact of droughts on agricultural productivity and instability of the characteristics of aridity in a changing climate [2]. However, to attribute the observed changes to either anthropogenic influence on climate or to natural processes (both external and internal to the Earth system), it is necessary to put these changes into the context of respective changes in the past climate epochs.

## 2. Description and comparison of models

This paper analyzes the spatio-temporal distribution of aridity characteristics in Europe based on the results of CMIP5 experiments (Climate Models Intercomparison project, phase 5; <https://cmip.llnl.gov/cmip5/>) [3], which reproduce the climate over the last 1000 years. In the CMIP5 nomenclature, these simulations are referred to as 'past1000' (for 850-1849 C.E.) and 'historical' (for 1850-2005 C.E.). We used the data of monthly mean values of the surface air temperature and precipitation models MPI-ESM-P (Max-Planck-Institute for Meteorology, Hamburg) [4] and IAP RAS CM (A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences) [5].

The following periods were chosen for the study:

- M0: the basic, pre-industrial period (1870 - 1899 C.E.);
- M1: the Medieval Climatic Optimum (1050 - 1200 C.E.);
- M2: the Little Ice Age (1600 - 1750 C.E.);
- M3: recent decades (1970 - 1999 C.E.).

The MPI-ESM-P is a state-of-the-art Earth system model. It implements ECHAM6 as an atmospheric general circulation model, MPIOM as an oceanic general circulation model and the module for simulating sea ice, JSBACH as a terrestrial biogeochemistry/vegetation dynamic module, and HAMOCC as an oceanic biogeochemistry module. All model compartments communicate via the OASIS coupler.



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

The climate model developed at the A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences (IAP RAS CM) includes modules describing the state of the atmosphere, ocean, the active land layer, biogeochemical cycles, and processes associated with atmospheric electricity and atmospheric chemistry. It belongs to the class of climate models of intermediate complexity (EMICs) and participates in relevant international comparison projects. A specific feature of the model is the parameterization of synoptic variability in the atmosphere and ocean, which allows reducing the computation cost by two orders of magnitude. The model realistically reproduces climate change over a period of instrumental measurements and is used to estimate past and future climate changes on a ten-year and longer time scale [5].

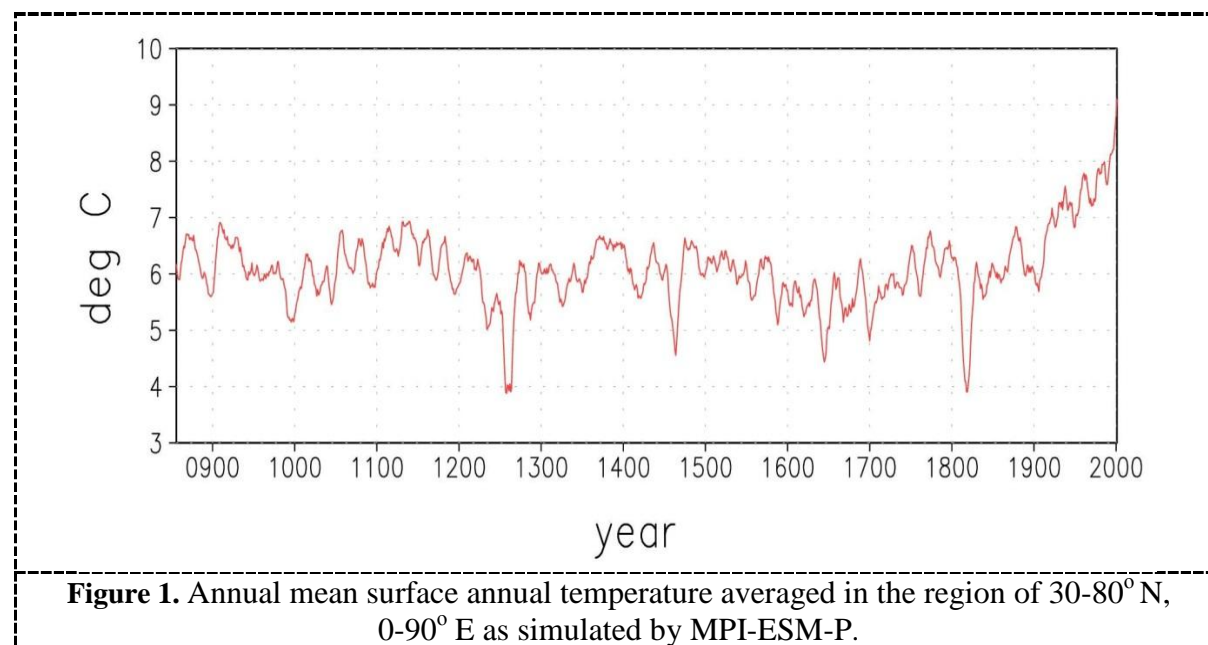
Both models were forced by:

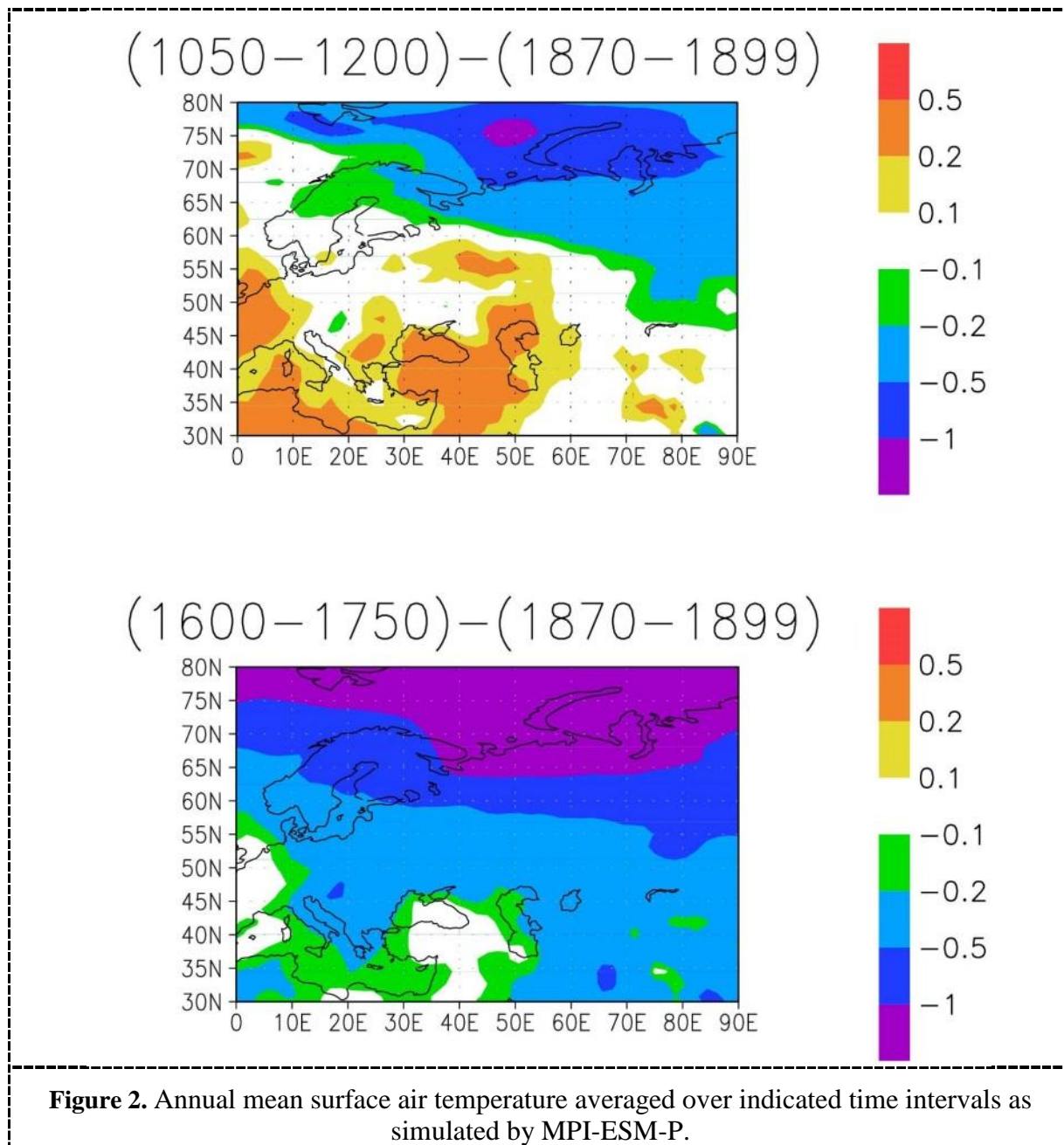
- (i) changes in the parameters of Earth's orbit;
- (ii) changes in total solar irradiance;
- (iii) changes in the extent of agricultural land (the MPI-ESM-P also parametrizes agricultural practice);
- (iv) reconstructed anthropogenic emissions of CO<sub>2</sub> in the atmosphere; atmospheric CO<sub>2</sub> concentration is calculated internally by carbon cycle routines of both models;
- (v) prescribed changes of other well-mixed greenhouse gases;
- (vi) tropospheric aerosol concentrations;
- (vii) reconstructed optical depth of volcanic aerosols in the stratosphere.

In addition, the MPI-ESM-P takes into account solar-induced ozone variations. More detailed information on these forcings is available in [6, 7].

### 3. Results

The MPI-ESM-P model realistically reproduces the long-term course of surface air temperature (Figures 1 and 2).



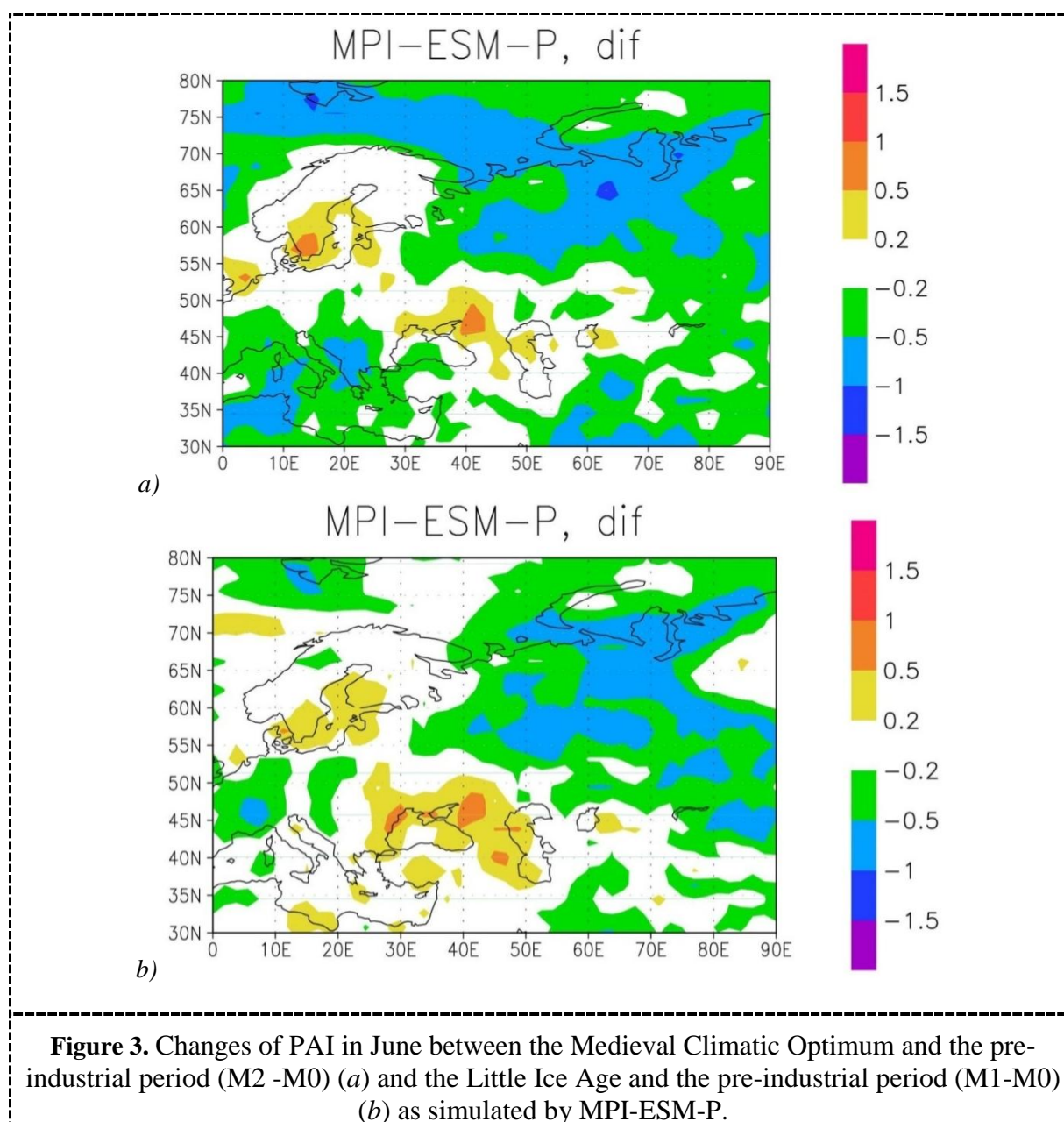


For each time interval (from M0 to M3), the Ped aridity index (PAI) [2] was calculated. We used only the data from May to August, because spring-summer droughts cause the greatest damage to agriculture and determine the functioning of natural terrestrial ecosystems. Statistical significance of the differences between time intervals M1, M2, M3 relative to M0 were estimated based on a two-sided t-criterion. The period from May to August was selected. In accordance with the typical practice of applying the PAI, the analysis was limited to Europe (which is defined in our paper as the region 30-80° N 0-90° E). We interpret positive changes of the PAI as a manifestation of a drier climate and its negative changes as a reflection of a more humid climate.

Then, for the entire summer period, PAI maps of changes between the Medieval Climatic Optimum and the pre-industrial period (M2-M0) and the Little Ice Age and the pre-industrial

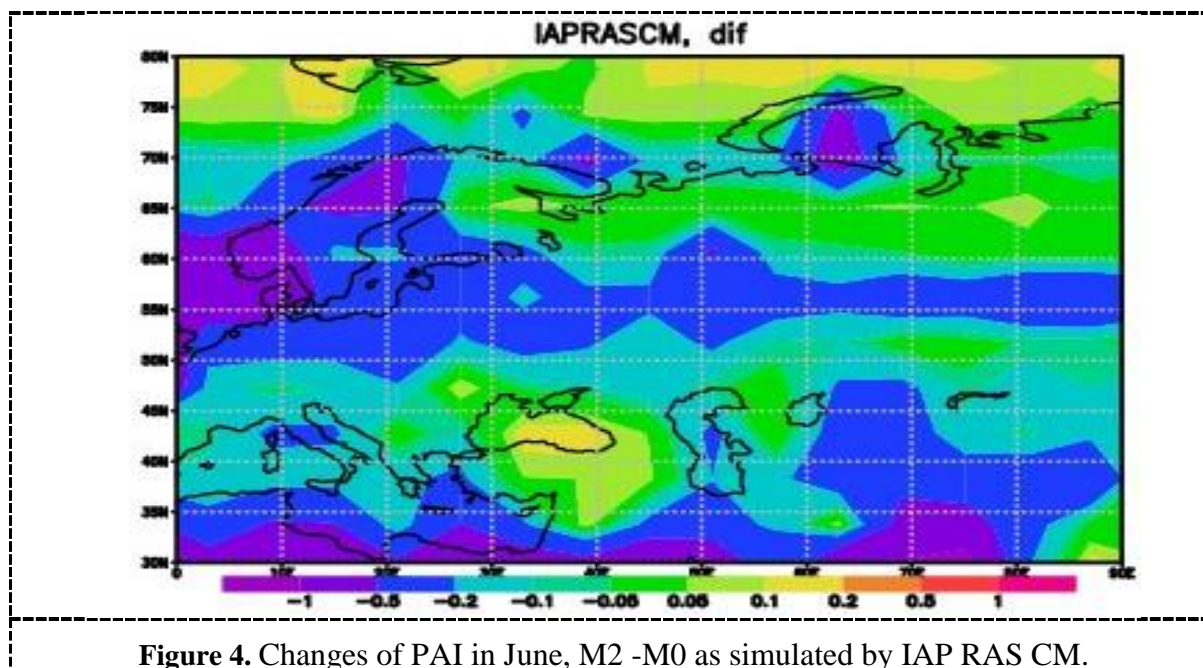


period (M1-M0) were constructed using the MPI-ESM-P. As an example, we present the PAI change maps for June (Figure 3*a, b*).



According to calculations with the MPI-ESM-P model, the Medieval Climatic Optimum is characterized by a marginally significant humidification in the Mediterranean (Figure 3*a*). In turn, the Little Ice Age is characterized by a more humid climate in northern Europe as compared with the pre-industrial period, although the changes are not statistically significant (Figure 3*b*). Similar conclusions on the MPI-ESM-P model are typical for the whole summer period.

Similarly, PAI maps were constructed for the entire summer period of changes in the index between the Little Ice Age and the pre-industrial period (M1-M0) using the IAP RAS CM. As an example, we present the PAI change maps for June (Figure 4).



**Figure 4.** Changes of PAI in June, M2 -M0 as simulated by IAP RAS CM.

According to calculations with the IAP RAS CM model, cooling in the Little Ice Age is characterized by a more humid climate in the North-Eastern Atlantic compared with the pre-industrial period, the changes are statistically significant. Similar conclusions on the IAP RAS CM model are typical for the entire summer period.

### Conclusions

This paper showed changes in the Ped aridity index (PAI) in Europe in the last millennium calculated with the climate model of the A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences (IAP RAS CM), and described the main results obtained by using this model in comparison with corresponding results obtained by using the climate model MPI-ESM-P. It has been shown that both models realistically reproduce the pre-industrial and the Little Ice Age climates and the current state of the climate system, as evidenced by a statistically significant Student's t-test.

Both models agree on a more humid climate in Northern Europe during the Little Ice Age. However, the models differ in the longitudinal position and statistical significance of these anomalies. In particular, the more eastward location of these anomalies and their larger statistical significance in the IAP RAS CM compared to those in the MPI-ESM-P might be caused by a more simplified dynamics in the former model. An immediate possible outcome of this simplified dynamics is an underestimated moisture transport from Atlantic to Europe, which controls the longitudinal position of the humid anomalies. Another possible consequence is an underestimation of the natural variability in the model, which boosts the statistical significance of the calculated changes.

### Acknowledgements

This work was supported by the Russian Foundation for Basic Research (grant 18-05-00087 A).

## References

- [1] *Global Risks 2017* URL: <http://reports.weforum.org/global-risks-2017/>
- [2] Cherenkova E A 2013 Quantitative estimates of atmospheric droughts in European Russia *Izv. RAS. Geographical series* **6** 76–85
- [3] Braconnot P, Harrison S P, Otto-Bliesner B *et al* 2011 The Paleoclimate Modeling Intercomparison Project contribution to CMIP5 CLIVAR Exchanges Special **16** 2 15–9
- [4] Bakker P, Stone E J, Charbit S *et al* 2013 Last interglacial temperature evolution – a model intercomparison *Climate of the Past* **9** 605 – 19
- [5] Eliseev A V, Mokhov I I 2011 Uncertainty of climate response to natural and anthropogenic forcings due to different land use scenarios *Adv. Atmos. Sci.* **28** 5 1215–32
- [6] Schmidt G A *et al* 2012 Climate forcing reconstructions for use in PMIP simulations of the last millennium (v1.1) *Geosci. Model Dev.* **5** 1 185–91
- [7] Taylor K E, Stouffer R J, Meehl G A 2012 An overview of CMIP5 and the experimental design *Bull Am Meteorol.* **93** 485–98