Wavy Jets and Arctic Climate Change

Professor Alan Haywood (School of Earth & Environment: SEE), Dr Dan Hill (SEE), Dr Julia Tindall

(SEE), Dr Aisling Dolan (SEE), Dr Jochen Voss (School of Mathematics)

Project partner(s) Participants of the Pliocene Model Intercomparison Project Phase 2

Contact email: earamh@leeds.ac.uk

Rising temperatures due to the emission of greenhouse gases may be changing atmospheric circulation (Petrie et al. 2015). This is being seen through changes in regional weather patterns, and in the frequency and intensity of extreme weather events (Dong et al. 2013). One of the most critical components of atmospheric circulation influencing European climate is the jet stream, which consists of ribbons of strong winds that move weather systems across the continent.

Over the last several years, including the summer of 2018, patterns of unusually persistent dry/warm or wet weather across Europe have been attributed to the changing behaviour of the jet stream (Dong et al., 2013). The unusual behaviour of the jet stream may be linked to the loss of Arctic sea-ice and the resulting increased temperatures in the northern hemisphere high latitudes (Francis & Vavrus, 2015; Petrie et al., 2015). Therefore, understanding the changing nature of the Arctic, its relationship to jet stream behaviour, and European weather/climate is of critical importance.

Warm intervals in the past provide science with a unique natural laboratory in which to investigate long-term environmental change, and climate models have been used to simulate past climate greatly enhance our understanding of atmospheric, oceanic and ice sheet behaviour (Haywood et al., 2016a). The most recent interval in the past known to have had a comparable atmospheric carbon dioxide (CO_2) level to today (~410 ppmv) was the Pliocene epoch (~3 million years ago). It was an interval known to be warmer than the pre-industrial era, with greatly reduced Arctic sea-ice (Figure 1 & 2), and shares a number of parallels to model predictions of climate for the end of this century (Haywood et al., 2016a).

In the context of an international climate modelling effort (see international partners section below), this project will use brand new climate model simulations to investigate the nature of the jet stream and connections to the Arctic in the Pliocene to greatly enhance our knowledge and understanding of past warm climates, and critically, their significance in the context of future climate change.

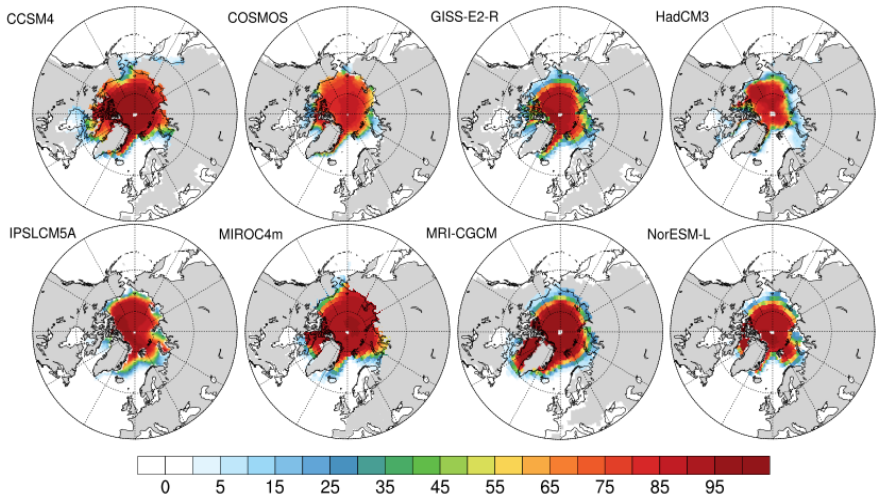

Figure 1: Mean Arctic sea ice concentrations (%) during summer in the **pre-industrial** simulated by 8 different climate models (Howell et al., 2016).

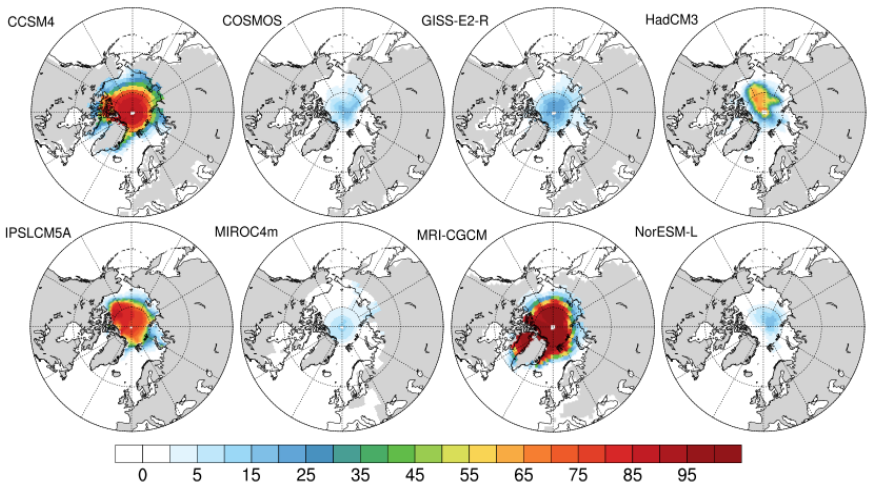

Figure 2: Mean sea ice concentrations (%) during summer in the **Pliocene** simulated by 8 different climate models (Howell et al., 2016).

Objectives

- Investigate and develop appropriate methods to diagnose the behaviour and variability of the jet stream.
- Examine the relationship between the large-scale features of Northern Hemisphere climate and jet stream behaviour.
- Assess model differences in the representation of the jet stream for the Pliocene through multi-model comparison.
- Examine the effect that different scenarios of Arctic warming have on model predictions of jet stream behaviour.
- Compare and contrast climate simulations for the European region during the Pliocene, which display different characteristics of jet stream flow, to available geological climate data.
- Compare and contrast Pliocene results with predicted jet stream behaviour using model experiments that simulate the climate of this century.

Potential for high impact outcomes

Understanding the relationships between Arctic sea-ice cover and jet stream behaviour for a climate of the past that has elevated concentrations of CO_2 will provide critical insights into weather and climate variability of the near future. The student will be guided by a brand new science plan recently formulated for the 2nd Phase of the Pliocene Model Intercomparison Project (Haywood et al., 2016b). Phase 1 led to the publication of many high impact papers in Nature journals. PlioMIP Phase 2 experiments are underpinned by the very latest syntheses of geological information available by the United States Geological Survey. The proposed research has the potential to contribute to the next Intergovernmental Panel on Climate Change Assessment Report.

Training

The PhD student will be embedded within a vibrant and dynamic research group in the School of Earth and Environment (Palaeo@Leeds). Palaeo@Leeds has experts in past climate and ice sheet modelling, as well as specialists in marine and terrestrial environments of the past. The student will be supported and fully trained in coupled ocean-atmosphere modelling. The student will analyse existing climate model simulations, learn to perform new experiments, learn how to compare results from different models, and learn appropriate methods for diagnosing the

behaviour of the jet stream. As such the student will become an expert in assessing atmospheric circulation relating to jet streams which will be broadly applicable to climate science in general. Our link to Jochen Voss in the School of Mathematics will provide the student with access to valuable expertise in numerical analysis of model results and statistics. The student will attend the Urbino Summer School in Palaeoclimatology (in Italy) and have the opportunity to attend various conferences during the project (e.g. American Geophysical Union Fall meeting in San Francisco and European Geoscience Union General Assembly in Vienna). Through our established collaborations the student will also have opportunities to visit and work with scientists from the Unites States Geological Survey as well other international modelling groups involved in the Pliocene Model Intercomparison Project Phase 2 (led by the University of Leeds and the U.S. Geological Survey) in the U.S., France, Germany, Norway and China. The research has cleat potential to make a highly valuable contribution to the next Intergovernmental Panel on Climate Change Assessment Report.

Student Profile

It is necessary for the candidate has an undergraduate degree (2.1 or better) in Atmospheric/Climate Science, Environmental Science, Earth Sciences, Mathematics or Physics. A keen interest in climate modelling is required, although previous experience of climate modelling is not required as our training will equip the student with all the skills necessary.

International Partners

Through our established collaborations the student will have an opportunity to interact and work with scientists from the Unites States Geological Survey as well other international modelling groups involved in the Pliocene Model Intercomparison Project Phase 2 in the U.S., France, Germany, Norway and China.

References

***Dong, B**., Sutton, R. and Shaffrey, L. (2014). The 2013 hot, dry summer in Western Europe. Bulletin of the American Meteorological Society, 95 (9). S61-S66. ISSN 1520-0477.*

***Francis J.A**. **and Vavrus, S.J**. (2015). Evidence for a wavier jet stream in response to rapid Arctic warming. Environmental Research Letters, 10, 014005.*

***Haywood, A,M**., Dowsett, H.J., Dolan, A.M. (2016a). Integrating geological archives and climate models for the mid-Pliocene warm period, Nature Communications, 7, doi: 10.1038/ncomms10646*

***Haywood, A,M.,** Dowsett, H.J., Dolan, A.M., Rowley, D., Abe-Ouchi, A., Otto-Bliesner, B., Chandler, M.A., Hunter, S.J., Lunt, D.J., Pound, M., Salzmann, U. (2016b). The Pliocene Model Intercomparison Project (PlioMIP) Phase 2: Scientific objectives and experimental design, Climate of the Past, 12, pp.663-675. doi: 10.5194/cp-12-663-2016.*

***Howell, F,W.,** Haywood, A.M., Otto-Bliesner, B.L., Bragg, F., Chan, W.L., Chandler, M.A., Contoux, C., Kamae, Y., Abe-Ouchi, A., Rosenbloom, N.A., Stepanek, C., Zhang, Z. (2016). Arctic sea ice simulation in the PlioMIP ensemble, Climate of the Past, 12, pp.749-767. doi: 10.5194/cp-12-749-2016.*

***Petrie, R. E**., Shaffrey, L. C. and Sutton, R. T. (2015). Atmospheric impact of Arctic Sea ice loss in a coupled ocean–atmosphere simulation. Journal of Climate, 28 (24). pp. 9606-9622. ISSN 1520-0442.*