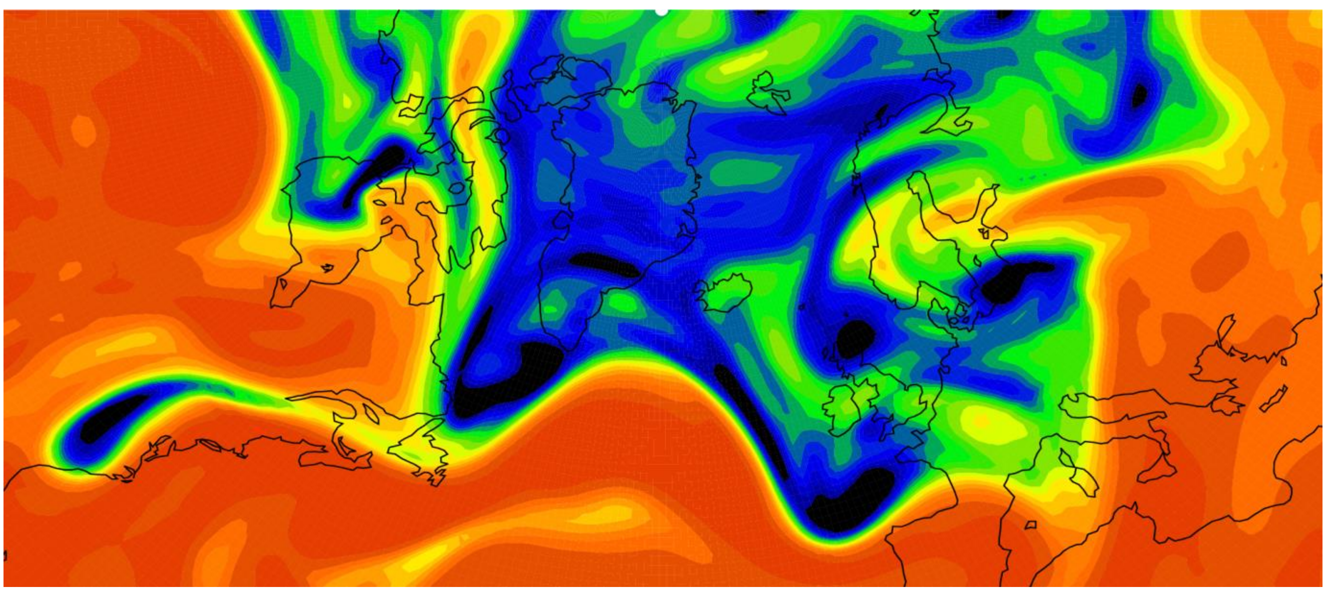
Explaining Timescales Associated with Jet Stream Variability

Lead Supervisor: John Methven, University of Reading, Department of Meteorology
Email: J.Methven@reading.ac.uk

Co-supervisors: Tom Frame, University of Reading, Department of Meteorology
Paul Berrisford, European Centre for Medium-Range Weather Forecasts

Extreme weather on a monthly or seasonal timescale is associated with persistent large-scale weather patterns. For example, the unusually wet summers of 2007, 2008 and 2012 in the UK were associated with a similar Rossby wave pattern on the jet stream where a "trough" remained almost stationary over the UK. A contrasting season was winter 2013/14 where the jet stream was directed at the UK and extreme seasonal rainfall resulted from a succession of cyclones. In both examples, the persistence in the latitude of the jet stream is a key player.



Jet stream follows a meandering path and is particularly strong across North Atlantic (sharp gradient from blue to red) at this time (23/7/07) in a season with persistent rainfall over the UK.

Research in the last decade has a revealed a systematic relationship between the time-mean latitude of jet streams and the timescale associated with persistence of variability about that state. The timescale for annular mode variability (associated with shifts in jet latitude or strength) is greater for jets located further equatorward (e.g., Barnes *et al.*, 2010). It is also found that climate models typically have much too great a persistence timescale. This has major ramifications since the fluctuation-dissipation theorem indicates that the magnitude of the response to forcing will increase with the persistence timescale (Ring and Plumb, 2008). Therefore, climate models may be too sensitive to forcing.

The relationship between persistence and jet latitude also appears to be more general than for annular modes. For example, Frame *et al.* (2013) have shown that across the North Atlantic the south jet state is associated with greater persistence. Furthermore, they show that the atmosphere is more predictable when starting in the south jet state, since weather forecast ensembles spread at a slower rate.

These results have been obtained by statistical analysis of re-analysis data, climate model simulations and weather forecasts. However, a theoretical understanding of the persistence is lacking. There are two hypotheses that may explain the persistence that will be tested in this PhD project:

1. The timescale is an intrinsic property of the unforced leading modes of variability. The timescale can be predicted from mode structure which is sensitive to the latitude of the jet upon which they exist.
2. The greater persistence in the equatorward jet state is related to the dominance of cyclonic Rossby wave breaking and repeated generation of long-lived coherent structures where the jet flows around the equatorward flank.

An opportunity exists to test these hypotheses by combining a novel diagnostic wave-mean flow framework (Methven and Berrisford, 2015) and the "empirical normal mode" technique (Brunet, 1994) which extracts mode structures from the perturbations. The power of the combination is that each mode has an intrinsic frequency that is a property only of its spatial structure and arises from fundamental conservation properties.

The theoretical framework can be applied to global meteorological analysis data. However, many complex phenomena occur simultaneously. The student will use the Reading intermediate general circulation model to conduct long simulations (10000 days) in an idealized configuration where the background state is maintained by weak relaxation (e.g., Sparrow *et al.,* 2009). These experiments will provide a less complex environment in which to apply the techniques and test the two hypotheses.

Training opportunities:

You will be part of the Dynamical Processes Group in Meteorology, enabling frequent interaction with experts in atmospheric dynamics. You will be able to visit the ECMWF regularly for research seminars and also meetings with the co-supervisor there. Your studentship will cover participation in a relevant summer school, the world-leading workshops at the ECMWF and conferences, both in the UK and abroad.

Student profile:

This project would be suitable for students with a degree in physics, mathematics or a closely related environmental or physical science. Enthusiasm for atmospheric science, including weather system dynamics would be valuable.

References:

Barnes *et al.* (2010), *Geophys. Res. Lett.,* **37**, L11804, doi:10.1029/2010GL043199.
Frame, Methven, Gray and Ambaum (2013), *Geophys. Res. Lett.*, **40**, 2411-2416, doi:10.1002/grl.50454.
Methven and Berrisford (2015), *Quart. J. Royal Meteorol. Soc.*, **141**, 2237-2258, doi:10.1002/qj.2518.
Sparrow *et al.* (2009), *J. Atmos. Sci.,* **66**, 3075-3094.

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