SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	Attributing predictable signals at subseasonal timescales to tropical forcing and surface boundary conditions
Computer Project Account:	spgbnort
Start Year - End Year :	2015 - 2017
Principal Investigator(s)	Warwick Norton
Affiliation/Address:	City Financial Investment Company Ltd (CFIC)
Other Researchers (Name/Affiliation):	Dan Rowlands (CFIC), Jason Beech-Brandt (CFIC), Ann Shelly (CFIC), Antje Weisheimer (University of Oxford)

Summary of project objectives

Primary Project Objective

1) Routine attribution of potentially predictable signals on subseasonal timescales (weeks 3-6).

Secondary Project Objectives

2) Establishing case studies that could be used for testing model improvements.
3) Suggesting areas where model improvements might increase predictive skill.

Summary of problems encountered

Our initial aim of using a T255L91 model and relaxing the tropics towards the L137 operational analysis proved too difficult to implement in the timescale of the project. Hence we used the established setup of a T255L60 model initialised (and relaxed) to ERA-Interim.

Issues were encountered in porting our experimental setup to the Broadwell nodes which has proved somewhat time consuming, both in personnel and computing resource. We had run failures that wasted resources and so requested an extra 500,000 SBU (which was granted) to complete our experiments for the 2015/16 winter.

The late arrival of ERA-interim in MARS means we finished relatively late the experiments for the 2016/17 winter. Ideally we would obtained the results much closer to real time (hopefully this will be available with ERA5 in a follow on project).

Experience with the Special Project framework

We greatly appreciate the opportunity to perform a Special Project. The results have increased our understanding of predictability and we look forward to achieving more results in a follow up project using ERA5.

We would like to thank Linus Magnusson and Paul Dando for providing support and helping with problems.

Summary of results

We performed 3 sets of experiments over the 2015/16 (23 weekly start dates from 20151012 to 20160314) and 2016/17 (16 weekly start dates from 20161031 to 20170213) winters with 51 member ensembles:

1. T255L60 control initialised from ERA-interim with observed SSTs.
2. As in 1 except fields between 15N-15S are relaxed to ERA-interim fields.
3. As in 2 except initial conditions are sampled over the previous 20 years (no initial conditions).

For each set of experiments we also ran an 11 member hindcast over 20 years (1995-2014) for each start date.

These are two very contrasting winters, 2015/16 had very strong El Nino conditions, while 2016/17 was weak La Nina and generally had weak mean atmospheric signals. For example the mean winter NAO in 2016/17 was closest to zero since 2002.

Figure 1 shows the weekly mean NAO (Figure 1a&b) and PNA (Figures 1c&d) indices for 2015/16 (grey) and the ensemble mean week 2 (blue), week 4 (red) and week 6 (black) forecasts for the control (Figures 2a&c) and tropical relaxation (Figure 1b&d) experiments. The skill in predicting the weekly variability in the NAO was low for weeks 4 & 6 in the control run (Figure 1a) though it did know about the overall positive NAO signal (the anomaly correlation skill mainly came from the seasonal signal). In the tropical relaxation experiments (Figure 2b) some of the weekly variability of the NAO was captured at week 4 and 6, and positive NAO signal was stronger. Notable in the control and tropical relaxation experiments is the lack of skill at week 4 in capturing the –ve NAO spike in early December and the +ve NAO spike in late January. For the PNA again the seasonal signal of +ve PNA is well captured in both models at week 4, with the tropical relaxation experiments capturing more of the weekly variability.

Note in the tropical relaxation runs the poorly forecast -ve PNA spike in December and the +ve PNA spike in early January. These two events are the precursors to the –ve and +ve NAO events in January. Examination of the weekly maps shows that the –ve PNA event produced a very wavy pattern which resulted in a Scandinavian block in early January which then transitioned to –ve NAO. The tendency for poor Euro-Atlantic forecast skill in –ve PNA via underestimation of blocking over Europe has been discussed by Ferranti et al (2014). The +ve PNA event was under forecast by all the models (including the tropical relaxation model) and the associated low pressure over eastern Canada. This low pressure subsequently moved east to give the strong +ve NAO event in late January.

Figure 2 shows the corresponding plots for 2016/17. Generally both the control and tropical relaxation experiments had no idea on the weekly variability of the NAO at weeks 4 and 6, particularly notable is the large forecast miss on the NAO in December where both models at week 4 and 6 were predicting –ve NAO yet what realised was strongly positive. The relaxed model had the idea that the NAO would increase from early to late winter (which is a typical pattern in La Nina winters). The control model also had no idea about the PNA, the week 6 mean was slightly positive yet there were several large –ve PNA events, consequently California had a record breaking wet winter! Particularly poorly forecast by the control was the –ve PNA period in December. In contrast the tropical relaxation experiment fixed the PNA! Other diagnostics (e.g. of the RMM1 index) showed the control (and operational monthly) had particularly poor skill in predicting tropical variability in the 2016/17 winter. This is part of the reason why the control (and operational monthly) had poor skill in predicting the PNA.

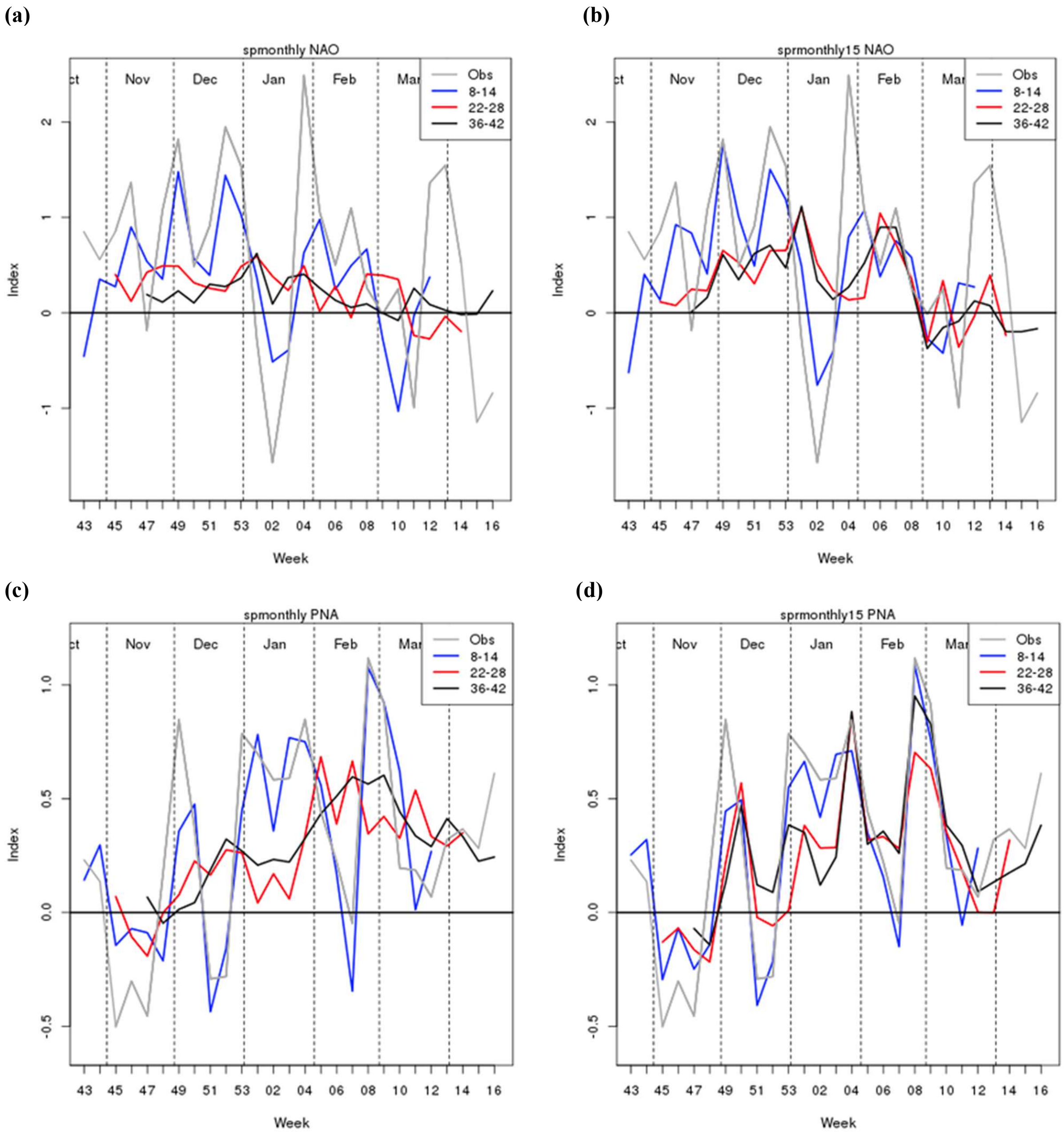


Figure 1. 2015/16 weekly mean NAO (a&b) and PNA (c&d) indices, observed (grey), ensemble mean forecast week 2 (blue), week 4 (red) and week 6 (black) for the control (a&c) and tropical relaxation (b&d) experiments.

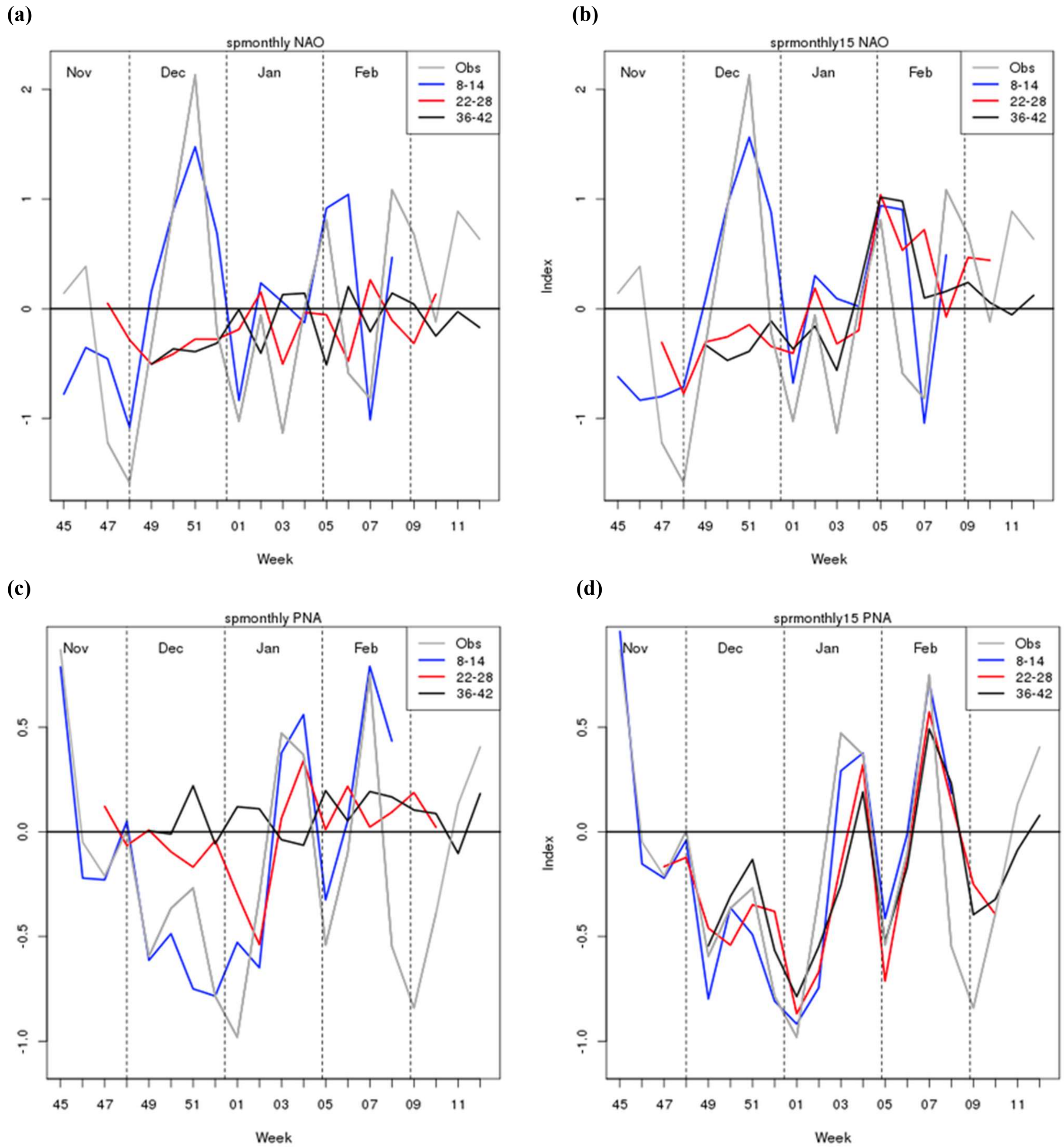


Figure 2. 2016/17 weekly mean NAO (a&b) and PNA (c&d) indices, observed (grey), ensemble mean forecast week 2 (blue), week 4 (red) and week 6 (black) for the control (a&c) and tropical relaxation (b&d) experiments.

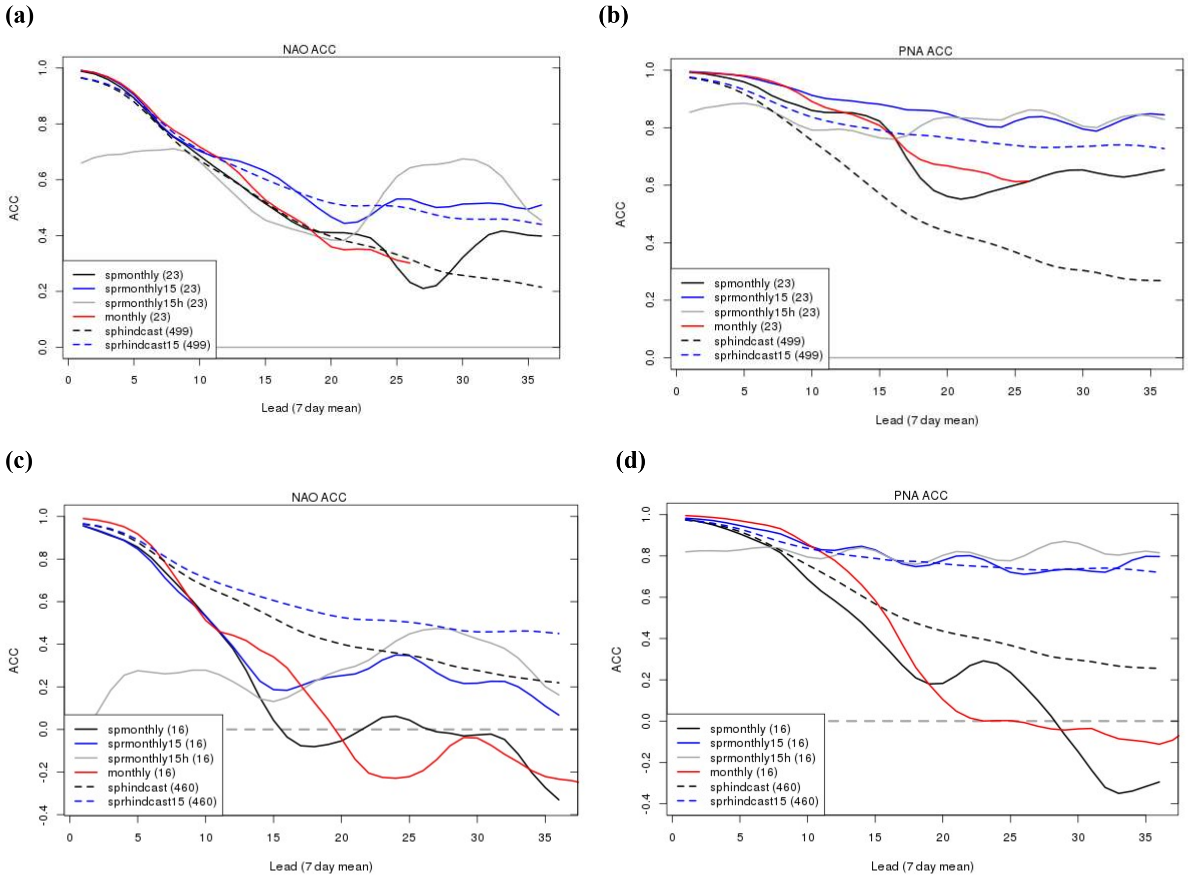


Figure 3. Anomaly correlation as a function of lead time for the NAO (a&c) and PNA (b&d) for the winters 2015/16 (a&b) and 2016/17 (c&d). Operational monthly (red), control experiment (black), tropical relaxation experiment (blue), no initial conditions (grey), dashed lines are average from the respective 20 year hindcasts.

A summary of the skill in the two winters is shown in Figure 3 as the anomaly correlation as a function of lead time for the NAO (Figure 3a&c) and PNA (Figure 3b&d). Also included on these figures (in red) is the anomaly correlation from the operational monthly (which has the same Monday start dates) and average skill estimated from the 20 year hindcasts (dashed). In 2015/16 the NAO skill (Figure 3a) of both the control and the operational monthly was close to average, the tropical relaxation experiments were more skilful but again close to the average of the tropical relaxation hindcast. As is normal in El Nino years, the skill of the PNA (Figure 3b) was above average for all models against their respective average.

In contrast, in 2016/17 the skill of the NAO (Figure 3c) was very low for day 10+. By day 15 the anomaly correlation of the control was close to zero while apparently the skill of the operational monthly was negative in week 4. In the tropical relaxation experiments the skill remained positive but significantly lower than average. For the PNA both control and operational monthly had low skill (though the control somewhat higher skill than the monthly in week 4). The tropical relaxation experiments had average PNA skill.

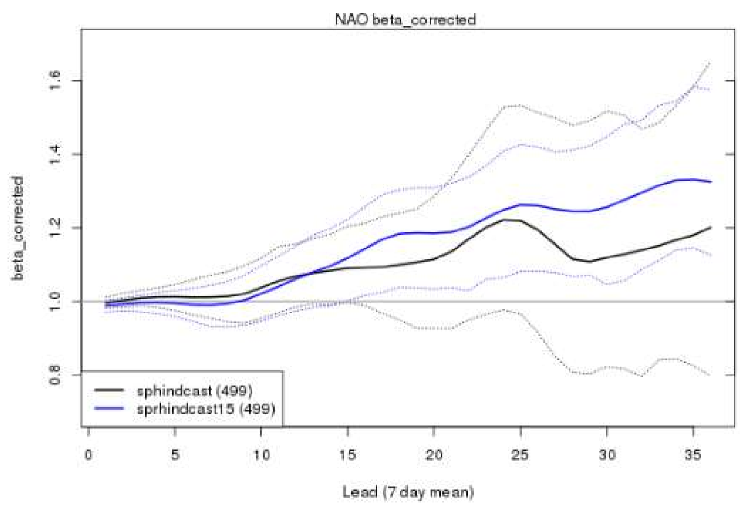
The no initial condition experiments (grey lines) have similar skill to tropical relaxed experiments (blue lines) by around the end of week 3 (day 21) indicating this is the point where initial conditions no longer add extra predictability over what comes from the tropical forcing. Interestingly the no initial condition experiments have higher skill in week 5 (day 30) than the experiment with initial conditions (though possibly this result is not significant given the sampling error).

Figure 4 shows an intriguing result from the 11 member 20 year hindcast experiments. Figure 4a shows the ratio of actual predictability of the NAO to potential predictability (i.e. taking one of the ensemble members as truth), Figure 4b is the equivalent figure for the PNA (we call this ratio beta). The fact that beta is greater than 1 for the NAO means the model is more skillful in predicting the real world than predicting itself or the model is under confident (this result was first found in seasonal hindcasts of GLOSEA5 by Scaife et al., 2014, & Eade et al., 2014, but appears across many models including operational ECMWF forecasts). Figure 4a shows that beta for day 15+ is higher for the tropics relaxed experiment than the control experiment (though not the sampling uncertainty on an 11 member ensemble at longer lead times is very large and this result is not significant). Even more striking is how the PNA changes from being over confident (beta < 0) in the control experiment to under confident (beta > 0) in the tropics relaxed experiment.

Our hypothesis is that in the control experiment, the large scale tropics (e.g. RMM1 pattern) is over confident, and because the PNA is strongly coupled to the tropics this also gives an over confident PNA forecast in the control experiment. Once you relax (fix) the tropics, under confidence of the PNA re-emerges (i.e. beta for the PNA becomes similar to beta for the NAO).

We have analysed diagnostics of tropical/extratropical coupling such as Rossby wave source which indicate the models have insufficient variability particularly in the central and eastern sub-tropical Pacific even in our tropics relaxed experiments. This suggests that models have too weak tropical/extratropical coupling most likely because of mean state errors particularly in the strength and position of the Pacific jet (see our 2017 progress report).

(a)



(b)

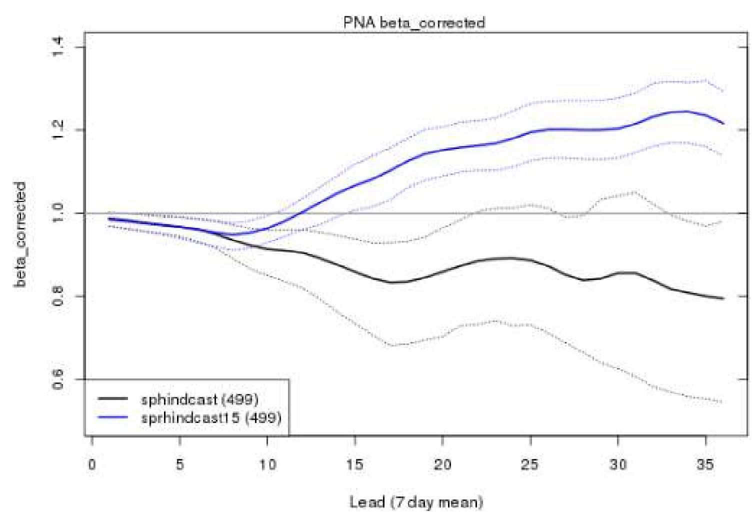


Figure 4. Ratio of observed predictability (ensemble mean correlation against observations) to potential predictability (ensemble mean correlation against an ensemble member) for (a) the NAO and (b) the PNA from the 11 member 20 year hindcast of the control experiment (black) and relaxed tropics experiment (blue). Dotted lines represent uncertainty bounds.

Discussion

From the original project objectives:

1) Routine attribution of potentially predictable signals on subseasonal timescales – even though we were unable to produce this in near real time (because of the delay in producing ERA-interim), we did analyse predictability in the winters of 2015/16 & 2016/17.
2) Establishing case studies that could be used for testing model improvements – the poor skill in both the NAO & PNA in December 2016 should be used in testing future models.
3) Suggesting areas where model improvements might increase predictive skill – reducing mean state errors of the Pacific jet and may lead to improvement in the strength of tropical teleconnections.

The result that tropical teleconnections are too weak in current subseasonal models suggests a conceptual model where they often show damped persistence of initial conditions rather than predictable signals emanating from the tropics. For instance with too weak teleconnections, the model may be unable to transition from +ve NAO to –ve NAO despite tropical convection being in the western hemisphere. This could explain the higher skill in weeks 5 & 6 in the no initial v tropics relaxed experiments in Figure 3 (though it would be good to test this also in a no initial conditions control experiment).

References

Eade, R., *et al* (2014), Do seasonal-to-decadal climate predictions underestimate the predictability of the real world? *Geophys. Res. Letts*, 41, 5620-5628.

Ferranti, L., *et al* (2014) Flow-dependent verification of the ECMWF ensemble over the Euro-Atlantic sector, *Q. J. R. Meteorol. Soc.* DOI:10.1002/qj.2411.

Scaife, A. A., *et al.* (2014), Skilful long range prediction of European and North American winters, *Geophys. Res. Letts.,* 41, 2514–1519.

List of publications/reports/presentations from the project with complete references

1) November 2016, Poster at ECMWF/ESA Workshop: Tropical modelling, observations and assimilation (Ann Shelly)
2) December 2016, Oral presentation at S2S extremes workshop (Warwick Norton)
3) December 2016, Oral presentation at AGU (Ann Shelly)
4) January 2017, Oral presentation at AMS (Warwick Norton)
5) February 2017, Seminar at ECMWF (Warwick Norton)

Future plans

We propose a two year extension of our Special Project where we will perform extended hindcast experiments over 1979-2016 (38 years) with a 37 member ensemble. We propose using ERA5 instead of ERA-interim (as used in our previous Special Project) as this will give a more accurate analysis of the tropical atmosphere. The period 1979-2016 is due to be completed for ERA5 by late 2018. Furthermore it could enable us to keep the experiments up to date (as was envisaged in this proposal) and extend the experiments back before 1979 (when those years become available in ERA5). The larger ensemble size and greater number of years will allow us to extend the analysis in this report.