SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year 2016

Project Title: Attributing predictable signals at subseasonal timescales to tropical forcing and surface boundary conditions

Computer Project Account: spgbnort

Principal Investigator(s): Warwick Norton

Affiliation: CFIC

Name of ECMWF scientist(s) collaborating to the project (if applicable) ……

Start date of the project: 1 January 2015

Expected end date: 31 December 2017

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	10000000	8498069.4	11000000	2129926.63
Data storage capacity	(Gbytes)				

Summary of project objectives
(10 lines max)

Primary Project Objective

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

Secondary Project Objectives

- Establishing case studies that could be used for testing model improvements.
- 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 has proved too difficult to implement in the timescale of the project. Hence we used the established setup of a T255L60 model that is initialised (and relaxed) to ERA-Interim.

The main issues encountered over the last few months were in porting our experimental setup to the new Broadwell nodes which has proved somewhat time consuming, both in personnel and computing resource. Problems have arisen from errors in the configuration and stability of the machine. Having access to only one system while the upgrade was going on also meant job throughput has necessarily been reduced. It is worth noting that a fair amount of our allocation for this year has been used in this porting exercise.

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

Summary of results of the current year

We have performed over 30 experiments where we have compared the operational monthly forecast with T255L60 experiments (atmosphere only with observed SSTs using 41r1 with 51 ensemble members) initialised from ERA-Interim and a corresponding set of experiments where the tropics have been relaxed towards ERA-Interim fields. Anomalies have been calculated from equivalent sets of hindcasts run over the previous 20 years with 11 ensemble members.

The start dates were chosen from periods when the operational monthly forecast performed poorly in weeks 3 & 4 in representing strong signals. Results so far have been analysed in terms of ensemble mean of upper level fields, e.g. 500 hPa heights, 200 hPa winds, velocity potential, stream function and Rossby wave source (RWS). In this report we present the results from 4 sets of experiments, two are winter cases and two are from summer.

Figure 1 shows the results from experiments initialised on 2 December 2013. The latter weeks of December 2013 (and much of early 2014) where characterised by very stormy conditions over the UK and cold over the eastern US, Figure 1d shows the z500 height anomalies from ERA-Interim for 23-29 December 2013. Notable is the very strong low pressure to the west of the UK and the strong ridging in the west of the US. The week 4 of the operational monthly forecast (Figure 1a) did not show either of these features, neither did our control experiment run with observed SSTs.

However the experiment run with relaxed tropics (Figure 1c) shows remarkable agreement to the analysed field.

To understand the differences in tropical forcing, we have examined the RWS terms and in particular the advective term (Qin and Robinson, 1993). To isolate the large-scale planetary component we have filtered this field to total wavenumber 5. Figure 1e shows this field (colours) with divergent field (arrows) at 200 hPa from the control experiment, and Figure 1f from the tropical relaxation experiment (which is very close to the equivalent plot from ERA-Interim). The colour scale is such that blue is cyclonic forcing and red is anticyclonic forcing. Figures 1e & 1f are shown for week 3 as we expect some lag in the response to the tropical forcing.

Figure 1f shows much stronger tropical forcing forcing across the Pacific and Atlantic than Figure 1e. The strong anticyclonic forcing across east Asia (from the strong divergent flow) results in a wave train across the northern Pacific that has a strong ridge in the western US. In the eastern Pacific there is convergent flow that gives cyclonic forcing and results in a cyclonic stream function in week 4 (not shown). This gives some weight to the idea of Julia Slingo (Met Office, 2014) that perhaps the origin of the storms over the UK was in fact in the east tropical Pacific.

Figure 2 shows the results of the second set of experiments initialised on 31 December 2012. There was a transition to –ve NAO in the latter part of January 2013 as shown by ERA-Interim in Figure 1d that shows 500 hPa height anomalies for 21-27 January 2013. The operational monthly forecast completely missed this transition and persisted a (weakly) +ve NAO state throughout January. The control experiment (Figure 2b) actually did better than the monthly forecast showing high pressure over Greenland and lows over the eastern US and western Europe which would project onto –ve NAO. However with tropical relaxation there is a much stronger –ve NAO forecast, in particular the storm track across the Atlantic is displaced further south.

In this case there are two contributing factors. In early 2013 there was a stratospheric warming and it is likely the control experiment simulated this better than the operational monthly forecast (even though it is significantly lower horizontal resolution) because the EPS/monthly forecast system at the time was still L62 and so did not have a well resolved stratosphere. However there was also a strong MJO event in January 2013 which was not well represented by the monthly or control experiment, e.g. Figures 2e & 2f show the advective RWS and divergent wind from the control and relaxation experiments in week 3. Very evident is the strong anticyclonic forcing and divergent flow in the central Pacific in the relaxation experiment which corresponds to MJO phase 6 – a well known precursor of transitions to –ve NAO (Cassou, 2008). So in summary, both the poor simulation of the stratosphere and the tropics contributed to the poor monthly forecast.

Figure 3 shows the results of the third set of experiments initialised on 8 June 2015. Over Europe in late June 2015 there was a transition to a “Spanish plume” situation with the transport of very warm air over the continent, see the strong high pressure signal for 29 June to 5 July 2015 in Figure 3d. At the same time the US moved into a configuration with a western ridge and cooler eastern trough. Week 4 of the operational monthly and the control forecast only had a very weak representation of the pattern over the US and none of the hot pattern for Europe. The tropical relaxation experiment had a good simulation of the pattern over the US and some representation of the high pressure over Europe. The tropical forcing in the relaxed experiments (Figure 3f) showed there was very strong divergent flow in central Pacific. It seems the circulation over the US and Europe has responded to this very strong tropical forcing that was under represented in the monthly and control forecasts. Overall we have found the extratropical response to tropical forcing to be weaker in summer compared with winter (and often with no response over Europe). However this episode had particularly strong forcing (due to the developing El Nino) and so did induce a significant extratropical response.

Figure 4 shows the results of the fourth set of experiments initialised on 24 July 2014. August 2014 was a particularly cool month in Europe characterised by persistent low pressure, e.g. see Figure 4d that shows 500 hPa height anomalies for 11-17 August 2014. The operational monthly forecast at week 4 (Figure 1a) showed a weak high pressure signal for northern Europe, the control (Figure 4b) and relaxed (Figure 4c) experiments showed somewhat stronger versions of the same pattern. None of these forecasts had any resemblance to the analysed pattern. There are some differences in the tropical forcing between the control and the relaxed experiments (compare Figures 4e & 4f) but apparently these were not responsible for driving the pattern over the Atlantic sector.

What all the models were missing is Hurricane Bertha that formed on 1 August and crossed the Atlantic giving severe rainfall to England on August 11. The remnants of the storm helped to transition Europe to a low-pressure dominated pattern for August, i.e. this is a clear example where a transition was not forced from a tropical teleconnection.

We have performed further experiments with a narrower band of tropical relaxation (i.e. ALATRX1=15 rather than 20 degrees). This does have some degradation of the results, e.g. the relaxation experiment initialised on 2 December 2013 (Figure 1c) doesn't form such a strong low pressure to the west of the UK. However we suspect it is a more "honest" experiment as relaxation out to 20 degrees may also give us part of the rotational response when what we really want to represent is what happens if the tropical divergent flow is more accurately simulated.

References

C. Cassou 2008, Intraseasonal interaction between the Madden–Julian Oscillation and the North Atlantic Oscillation, *Nature* **455**, 523-527.

Met Office 2014, The recent storms and floods in the UK, *The Met Office*.

J. Qin and W. Robinson 1993, On the Rossby wave source and the steady linear response to tropical forcing, *J. Atmos. Sci*. **50**, 1819-1823.

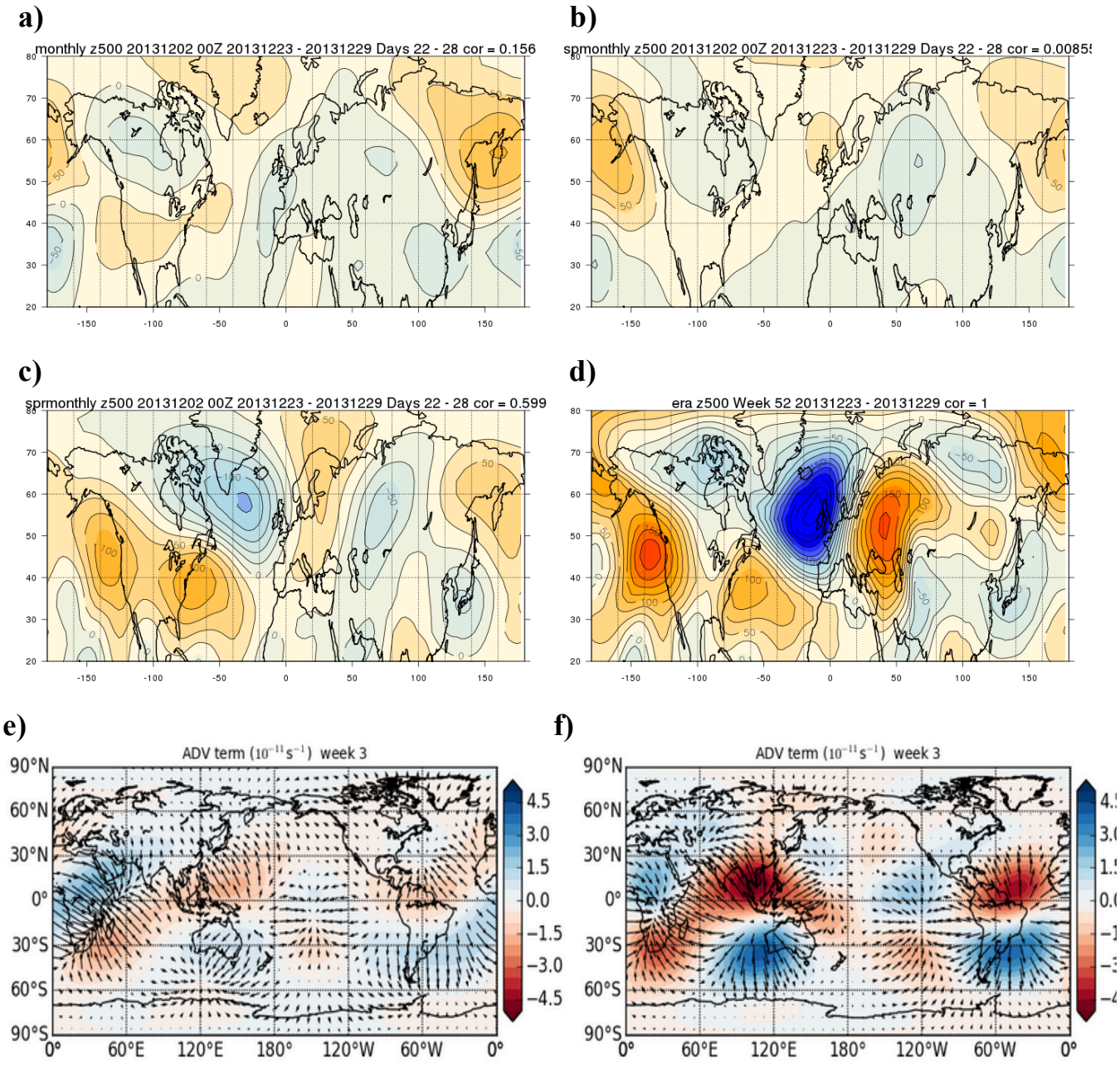

Figure 1. Model experiments initialised on 2 December 2013: a) operational monthly forecast z500 height anomaly for week 4; b) as for a) except control T255L50 forecast with observed SSTs; c) as for b) except with relaxed tropics; d) verifying analysis for 23-29 December 2013 from ERA interim; e) advective Rossby wave source term (colours) and divergent wind (arrows) for week 3 from control T255L50 forecast truncated to wavenumber 5; f) as for e) except with relaxed tropics.

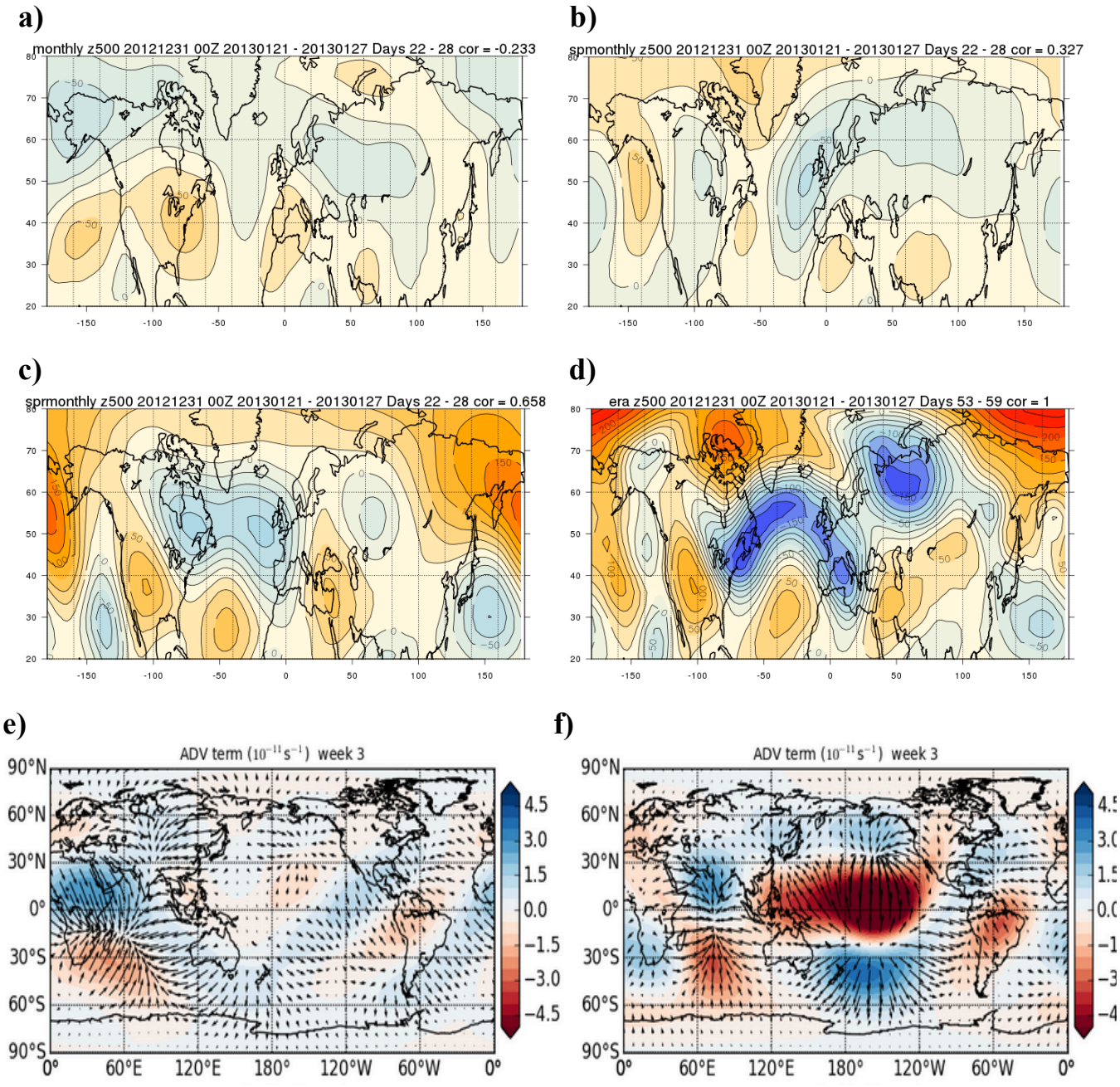

Figure 2. Model experiments initialised on 31 December 2012: a) operational monthly forecast z500 height anomaly for week 4; b) as for a) except control T255L50 forecast with observed SSTs; c) as for b) except with relaxed tropics; d) verifying analysis for 21-27 January 2013 from ERA interim; e) advective Rossby wave source term (colours) and divergent wind (arrows) for week 3 from control T255L50 forecast truncated to wavenumber 5; f) as for e) except with relaxed tropics.

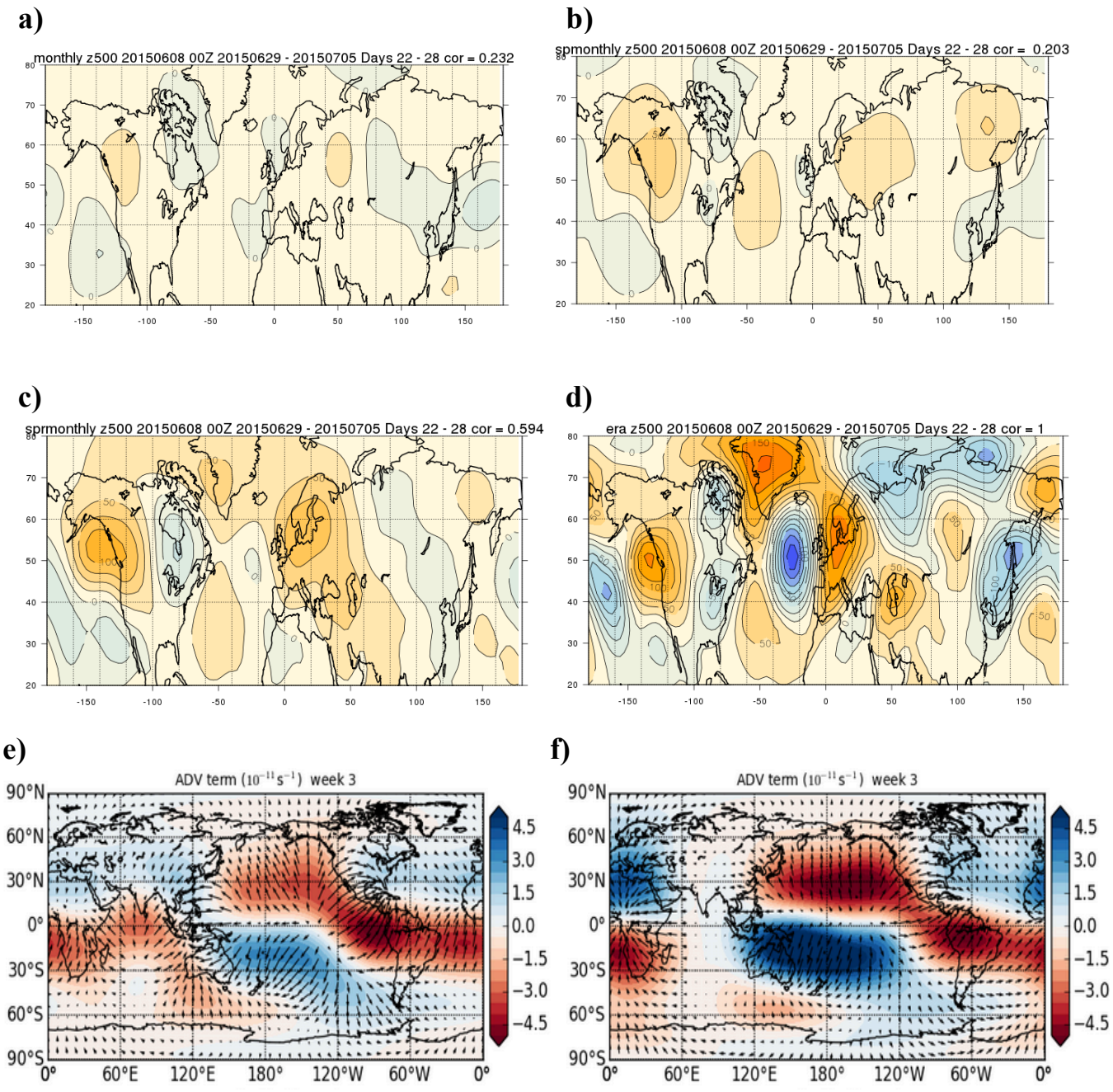

Figure 3. Model experiments initialised on 8 June 2015: a) operational monthly forecast z500 height anomaly for week 4 (days 22-28); b) as for a) except control T255L50 forecast with observed SSTs; c) as for b) except with relaxed tropics; d) verifying analysis for 29 June to 5 July 2015 from ERA interim; e) advective Rossby wave source term (colours) and divergent wind (arrows) for week 3 from control T255L50 forecast truncated to wavenumber 5; f) as for e) except with relaxed tropics.

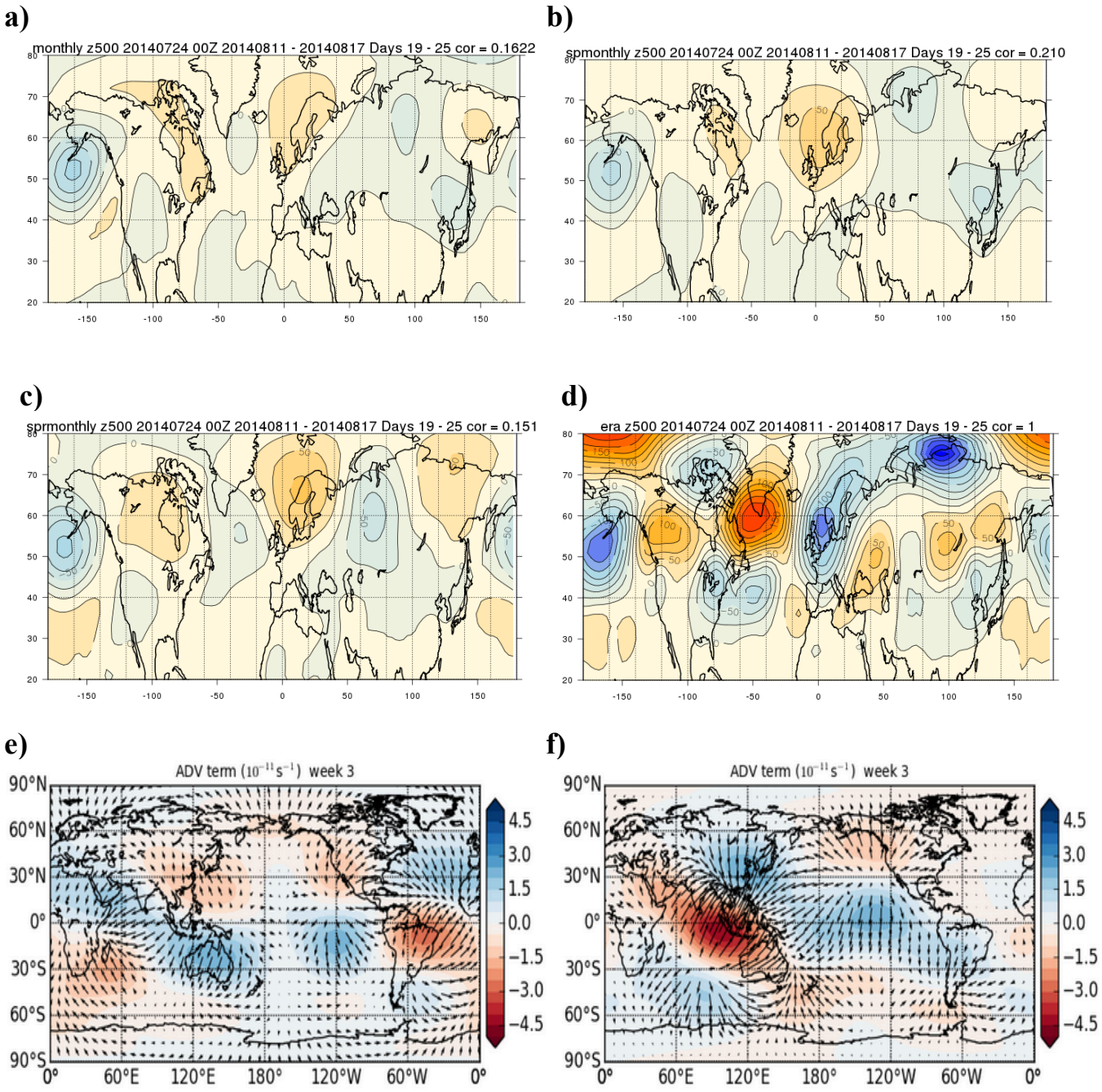

Figure 4. Model experiments initialised on 24 July 2014: a) operational monthly forecast z500 height anomaly for week 4 (days 22-28); b) as for a) except control T255L50 forecast with observed SSTs; c) as for b) except with relaxed tropics; d) verifying analysis for 11-17 August 2014 from ERA interim; e) advective Rossby wave source term (colours) and divergent wind (arrows) for week 3 from control T255L50 forecast truncated to wavenumber 5; f) as for e) except with relaxed tropics.

List of publications/reports from the project with complete references

None.

Summary of plans for the continuation of the project

There have been some very strong tropical signals over the 2015/16 winter with generally the monthly forecast system under representing the subseasonal variability (see Figure 5). We have started running our set of experiments over this winter (initialising every Monday to compare with the operational monthly forecast). Our objectives are to:

- Attribute in a more systematic way (compared to choosing ad hoc start dates) the role of the tropics in extratropical predictability, additionally using the hindcast relaxation experiments over the past 20-years.
- Further develop the Rossby wave source methodology of looking at tropical forcing and extratropical teleconnections.
- Gain more understanding of the predictable errors in the tropical divergent flow in the monthly forecasts.

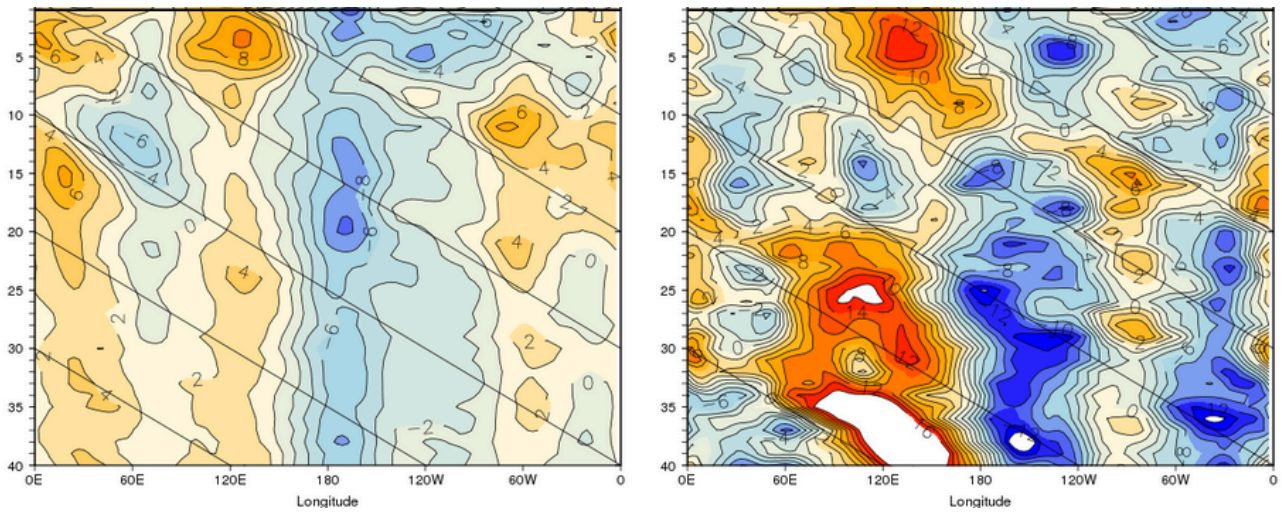

Figure 5. Hopfmueller plot of equatorial 200 hPa velocity potential from 2 December 2015 monthly forecast (left) and analysis (right).