S-RIP Implementation Plan

Version 1.0, February 2014

Motivation and Goals

The middle atmosphere and climate community use reanalyses widely to understand atmospheric processes and variability in the middle atmosphere, to validate climate models (e.g. CCMVal, CCMI), and, potentially, for trend analysis. Yet different reanalyses give different results for the same diagnostic - for example the global energy budget and hydrological cycle, the Brewer-Dobson circulation, stratospheric vortex weakening and intensification events, and large-scale wave activity at the tropical tropopause. There is thus a need for a coordinated reanalysis intercomparison project that shall start a comprehensive activity to compare all appropriate reanalysis data sets for "key" diagnostics to help understand the causes of differences and to use the results to provide guidance on appropriate usage of various reanalysis products in scientific studies. In addition, the reanalysis community will benefit from coordinated user feedback, which can lead to improvements in the next generation of reanalysis products.

The SPARC Reanalysis Intercomparison Project (S-RIP) is an emerging SPARC activity that was proposed in 2012 (Fujiwara et al., 2012; Fujiwara and Jackson, 2013). The goals of S-RIP are to:

1) Create a communication platform between the SPARC community and the reanalysis centres
2) Understand current reanalysis products and to contribute to future reanalysis improvements in the middle atmosphere region
3) Write up the results of the reanalysis intercomparison in peer reviewed papers and a SPARC report.

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Scope

By August 2012, a Working Group had been formed, and the reanalysis centre contacts for the project had been confirmed. The Working Group discussed chapter titles, co-leads, and initial contributors to the final SPARC report and organised an S-RIP Planning Meeting, which was held at the Met Office, Exeter, UK, from 29 April-1 May 2013. The purposes of the meeting were to finalise the report outline, to determine the diagnostics list and observational data for validation required for each chapter, to agree on the general guidelines and protocols, and to define the project timetable

At the meeting it was decided that the project would focus predominantly on reanalyses (although some chapters may include diagnostics from operational analyses). Available and soon to be available reanalyses are shown in Table 1. For most of the chapters, we will compare newer reanalyses, *i.e*., MERRA, ERA-Interim, JRA-25/JCDAS, JRA-55, NCEP-CFSR, and 20CR. We also aim to include ERA-20C, ERA-SAT, MERRA-2, *etc*., when available. Some chapters may include older reanalyses such as R-1, R-2, and ERA-40, because they have been heavily used in the past and are still being used for certain studies, and to gain insight into potential shortcomings of past research results. For some chapters, only a subset of these reanalyses shall be used, since some reanalyses have already been shown to be poor for some studies (eg ERA-40 for polar processes), or do not extend to high enough levels (eg 20CR does not extend above the stratopause). At the beginning of each chapter an explanation will be given as to why specific reanalyses were included or excluded. The intercomparison period is 1979-2012, *i.e*., "the satellite era," but some chapters will also consider the pre-satellite era before 1979. Given the wide use of ERA-40 (which only runs to 2002) a separate intercomparison for 1979-2002 shall be carried out for some diagnostics and placed in an Appendix.

Table 1. Global atmospheric reanalysis datasets available or soon to become available (latter in square brackets)

Reanalysis Centre	Name of the Reanalysis Product

ECMWF	ERA-40, ERA-Interim, [ERA-20C], [ERA-SAT]
NOAA/NCEP	NCEP/NCAR (R-1), NCEP/DOE (R-2), NCEP-CFSR
JMA	JRA-25/JCDAS, JRA-55
NASA	MERRA, [MERRA-2]
NOAA – CIRES	20CR

Outline Plan for S-RIP Report

Summarised below are the draft plans for the S-RIP final report. Issues related to transport processes and gravity wave issues will be distributed amongst several chapters.

Chapter 1: Introduction. The S-RIP motivation, goals, rationale and report structure are described.

Chapter 2. Description of the reanalysis systems. This chapter will include a detailed description of the forecast model, assimilation scheme and observational data assimilated for each reanalysis, together with information on each reanalysis "stream" and on what data are archived.

Chapter 3. Climatology and interannual variability of dynamical variables. A climatology of major dynamical variables (eg zonal mean temperature, zonal mean wind), created from an ensemble of the newer reanalyses for the period 1979-2012 (1979-2002, allowing comparison with ERA-40, in the appendix) will be created on both standard pressure levels and potential temperature levels. Various key plots of the ensemble climatological means and individual reanalysis anomalies from these means will be created and presented in an online atlas. Inter-reanalysis variations will be quantified. Independent observations (ie not used in the reanalyses) which can be used for validation include radiosondes, lidars, rocketsondes and various satellites.

Chapter 4. Climatology and interannual variability of ozone and water vapour. This chapter will include a detailed evaluation of ozone and water vapour in the reanalyses using a range of observations obtained from sonde, aircraft, and satellite instruments. The diagnostics considered will include climatological evaluations, seasonal cycles, interannual variability, and trends. Other, more event-based diagnostics such as the tape recorder, QBO, and polar dehydration will be used to understand differences in the climatological evaluations, while detailed analysis of these processes will be covered in the "advanced" chapters. In addition, relevant information on the assimilated ozone and water vapour, and the prognostic representation of these fields in the reanalyses will be summarized.

Chapter 5. Brewer-Dobson circulation. This chapter will evaluate stratospheric circulation using diagnostics such as the age-of-air (mean age and spectrum), metrics for the strength of mixing barriers, and residual circulation quantities. Tendencies for heat and momentum as well as analysis increments will be considered. Eulerian chemistry transport models and trajectory calculations will be used. Results will be validated against satellite, ground-based, balloon, and aircraft observations of SF_6, CO_2, and NO_2, including the recent MIPAS datasets. Both climatological results and trends in the main diagnostics will be examined.

Chapter 6. Stratosphere-troposphere coupling. This chapter covers two-way coupling between the troposphere and stratosphere, focusing in particular on extra-tropical coupling on daily to intraseasonal time scales, and how this shorter-term variability is modulated on interannual time scales (*e.g*., by ENSO). The chapter will synthesize and compare established approaches with more recent metrics to characterize planetary wave coupling and blocking, coupling of the zonal mean flow (*e.g*. the annular modes), and the mechanism(s) connecting the stratosphere and troposphere (*e.g*., changes in tropopause height). There has been recent discussion on how to best characterize Stratospheric Sudden Warmings (SSWs). The established and alternative definitions of SSWs and the resulting impact on diagnostics of stratosphere-troposphere coupling will be explored.

Chapter 7. Extra-tropical UTLS. The diagnostics to be produced will include tropopause characterisation by commonly used methods, multiple tropopause characteristics, the tropopause inversion layer, UTLS jet characteristics, estimates of horizontal boundaries between the ExUTLS and TTL, air parcel histories using trajectory calculations, and measures of Rossby wave breaking. These diagnostics will be related to analysis of stratosphere-troposphere exchange (STE). This chapter will also have a section that reviews diagnostics commonly applied to both the ExUTLS and TTL.

Chapter 8. TTL. The diagnostics will include the general TTL structure (cold point and lapse rate tropopause, *etc.*), clouds and convection (cloud fraction profiles, OLR, *etc.*), diabatic heat budget, transport (Lagrangian cold point, residence time based on vertical winds and heating rates, *etc*.), wave activity, and long-term changes (*e.g*., tropical belt widening).

Chapter 9. QBO and tropical variability. Diagnostics for this chapter will include analysis of the tropical QBO, its extra-tropical teleconnections (as well as other relevant teleconnections such as with ENSO and the solar cycle), its zonal momentum budget, and spectral characteristics of tropical waves including modal analysis and equatorial wave energetics. Observations for validation include operational and campaign radiosondes, rocketsondes, and satellites such as HIRDLS and SABER. Information regarding non-orographic gravity wave parameterization (if present) and analysis increments may also be utilised.

Chapter 10. Polar processes. This chapter will cover the formation of polar stratospheric clouds, chlorine activation, denitrification and dehydration, and (possibly) chemical ozone loss in the lower stratospheric winter polar vortices. Focus will be on process-oriented and case studies. The chapter will also include a review of previous works showing significant biases in lower stratospheric temperature, winds, or vortex strength / structure / evolution which render some reanalyses (*e.g*., R-1, R-2, and ERA-40) unsuitable for polar process studies.

Chapter 11. USLM. This chapter will look at diagnostics including the Semi-Annual Oscillation, climatology of the winter polar vortex, SSWs (focusing on stratopause evolution and mesospheric cooling), waves (eg tides, the two-day wave, and normal modes), inertial instability at the tropical stratopause, and Hadley circulation in the stratopause region. Observations including SABER, MLS, the NDACC database, and CMAM30 (a model nudged to reanalysis), will be used for validation purposes and to extend our knowledge of the state of the middle atmosphere. NOGAPS–ALPHA may also be considered for case studies.

Chapter 12. Synthesis Summary.Key findings, common patterns in results, recommendations for future research and reanalysis development are summarized.

Schedule

We shall finalize the "basic" chapters (*i.e*., Chapters 1-4) within 2 years after the S-RIP Planning Meeting. The "advanced" chapters (5-12) will evolve slightly more slowly, with an interim report on these chapters every year. The plan is as follows. Top Level deliverables are in **bold.**

May 2014:

- ◦ Basics in place for reanalysis intercomparison – reanalysis and observational data downloaded, diagnostics being developed, initial results produced
- Write progress report for SPARC SSG

May 2015:

- **complete "Basic" chapters (Chapters 1-4)**
- complete interim (first draft) Chapters 5-11

May 2016

- Write progress report for SPARC SSG

May 2018

- **complete "Advanced" Chapters (Chapters 5-12) and whole report**
- **review S-RIP and decide on extension of activity**

A further key part of S-RIP will be to write peer-reviewed papers. This will be done at any appropriate time. Wherever possible, the aim will be to write these papers prior to completion of the report, rather than the other way around. This avoids problems with citations of original research.

Management

S-RIP is co-led by Masatomo Fujiwara (Japan) and David Jackson (UK). The co-leads are members of a wider Working Group, who help steer the direction of the project and coordinate the specifics of the work. Working Group members are David Tan (UK), Thomas Birner (USA), Simon Chabrillat (Belgium), Sean Davis (USA), Yulia Zyulyaeva (Russia), Michaela Hegglin (UK), Kirstin Krueger (Germany), Craig Long (USA), Susann Tegtmeier (Germany), Gloria Manney (USA).

Each reanalysis centre also has a contact who is involved in S-RIP and whose presence is vital to ensure the two-way flow of knowledge between researchers and the reanalysis centres. The reanalysis centre contacts are David Tan (ECMWF), Craig Long (NCEP), Wesley Ebisuzaki (NCEP), Kazutoshi Onogi (JMA), Yayoi Harada (JMA), Steven Pawson (NASA/GMAO), Gilbert Compo (NOAA), Jeffrey Whitaker (University of Colorado).

Each chapter of the report has nominated co-leads who organise the production of relevant diagnostics and the chapter writing. The chapter co-leads are shown in Table 2. Thirty-five scientists from 10 countries have expressed their wish to be Chapter Leads or Contributing Authors for S-RIP. This number will grow as the project develops.

Table 2. Chapter titles and co-leads

	Title	Co-leads
1	Introduction	Masatomo Fujiwara, David Jackson
2	Description of the Reanalysis System	Masatomo Fujiwara, David Tan, Craig Long
3	Climatology and Interannual Variability of Dynamical Variables	Craig Long, Masatomo Fujiwara
4	Climatology and Interannual Variability of Ozone and Water Vapour	Michaela Hegglin, Sean Davis
5	Brewer-Dobson Circulation	Thomas Birner, Beatriz Monge-Sanz
6	Stratosphere-Troposphere Coupling	Edwin Gerber, Yulia Zyulyaeva
7	ExUTLS	Cameron Homeyer, Gloria Manney
8	TTL	Susann Tegtmeier, Kirstin Krüger
9	QBO and Tropical Variability	James Anstey, Lesley Gray
10	Polar Processes	Michelle Santee, Alyn Lambert
11	USLM	Diane Pendlebury, Lynn Harvey
12	Synthesis Summary	Masatomo Fujiwara, David Jackson

Monitoring of the project will be via progress reports written by chapter co-leads every 6 months (with the option of associated telecons for further discussion). Further workshops are also planned:

- Mid/late 2014 (location – probably NCEP (USA)) – planning for writing of papers and completion of "Core" chapters 1-4 and an interim report for chapter 5-11)
- Late 2016/early 2017 (location TBD) – planning for writing of papers and completion of full report.

Dissemination of up-to-date project information will be made available through the S-RIP website at http://s-rip.ees.hokudai.ac.jp/.

We will archive the processed data that are used for the figures/tables in the report at the British Atmospheric Data Centre (BADC).

Links to Other Projects

S-RIP has developed links to SPARC projects SNAP (SPARC Network on Assessment of Predictability) and SPARC-DAWG (Data Assimilation Working Group) through the obvious links in stratospheric analyses and impacts of analyses on stratospheric forecasting that these groups also work on. Reanalyses are widely used to validate climate models and thus there are clear linkages between the activities of S-RIP and of CCMI. There is also scope for interaction with the SPARC activities on Temperature Trends and Trace Gas / Aerosol Climatologies. Leading members of these three activities are also in the S-RIP Working Group, thus enhancing opportunities for co-ordination and collaboration. S-RIP has been publicised at WGNE (WMO Working Group on Numerical Experimentation) meetings, where the project has been received well. Ideas for a parallel WGNE activity focused on tropospheric reanalyses have been discussed. S-RIP activities have the potential to be important components of the Global Framework for Climate Services.

Prospects for the future

S-RIP is planned to last for 5 years. However, given that a goal of S-RIP is to feed back scientific results to the reanalysis centres (thus forming a “virtuous circle” of assessment => improved reanalyses => more assessment => further improvement in reanalyses), and that most reanalysis centres have in any event ongoing programmes to deliver new, improved reanalyses, it would be valuable to continue S-RIP beyond its initial 5 years. It is thus critical to review the value of S-RIP with the research community, reanalysis centres and the SPARC SSG after its first 5 years to determine whether, and if so in what form, S-RIP should continue. It is hoped that some support from SPARC will be maintained if it is decided that S-RIP should continue longer.

It is important that the project has a lasting legacy to sustain the international interest in the assessment of reanalyses. A prime legacy of the project is likely to be development of links between researchers and reanalysis centres that mean future reanalysis developments will use the outcomes from S-RIP assessments of reanalyses in a systematic, standardised way, rather than the more ad hoc approaches that may pertain at present. A further legacy will be a data archive (at BADC) of reanalyses datasets, at standard resolution to enable ease of intercomparison without further processing, and which will be freely available to researchers world-wide and will continue to be a useful means of assessing reanalyses beyond the lifetime of the project.

References

Fujiwara, M., S. Polavarapu, and D. Jackson, **A proposal of the SPARC Reanalysis/Analysis Intercomparison Project**, *SPARC Newsletter*, No. 38, 14-17, January 2012.

Fujiwara, M., and D. Jackson, **SPARC Reanalysis Intercomparison Project (S-RIP) Planning Meeting, 29 April-1 May, 2013, Exeter, UK**, *SPARC Newsletter*, No. 41, 52-55, July 2013.