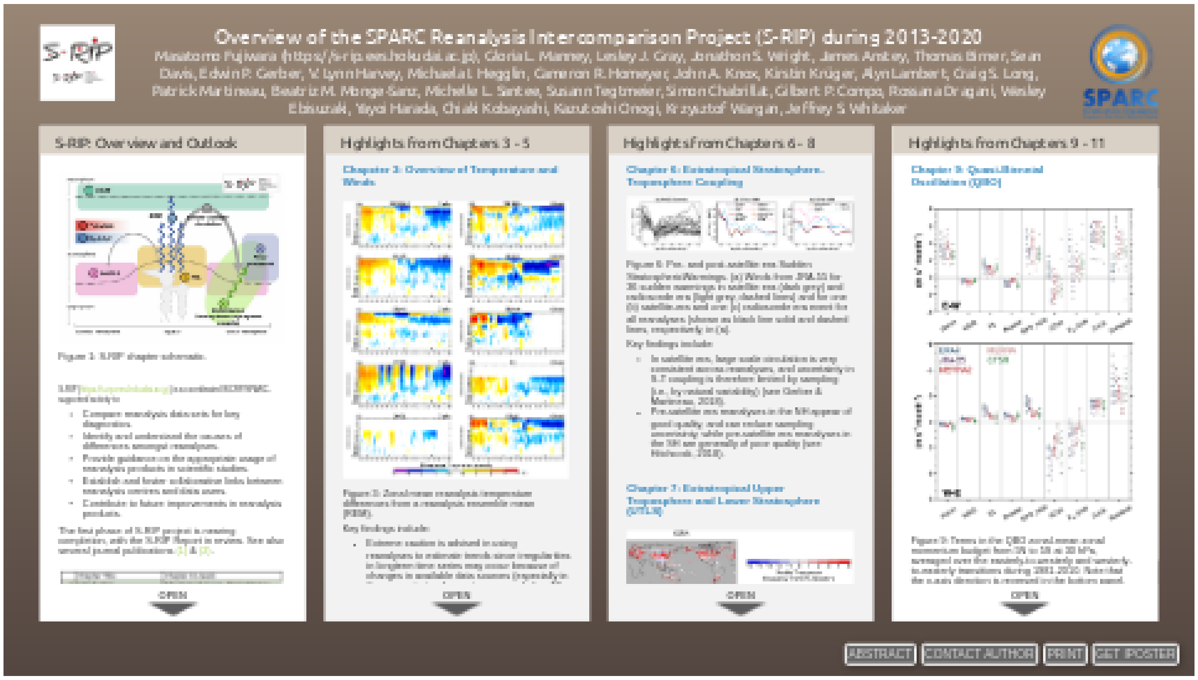
Overview of the SPARC Reanalysis Intercomparison Project (S-RIP) during 2013-2020



Masatomo Fujiwara (https://s-rip.ees.hokudai.ac.jp), Gloria L. Manney, Lesley J. Gray, Jonathon S. Wright, James Anstey, Thomas Birner, Sean Davis, Edwin P. Gerber, V. Lynn Harvey, Michaela I. Hegglin, Cameron R. Homeyer, John A. Knox, Kirstin Krüger, Alyn Lambert, Craig S. Long, Patrick Martineau, Beatriz M. Monge-Sanz, Michelle L. Santee, Susann Tegtmeier, Simon Chabrillat, Gilbert P. Compo, Rossana Dragani, Wesley Ebisuzaki, Yayoi Harada, Chiaki Kobayashi, Kazutoshi Onogi, Krzysztof Wargan, Jeffrey S. Whitaker

ENTER NAMES OF AFFILIATED INSTITUTIONS

PRESENTED AT:

AGU FALL MEETING
Online Everywhere | 1–17 December 2020

S-RIP: OVERVIEW AND OUTLOOK

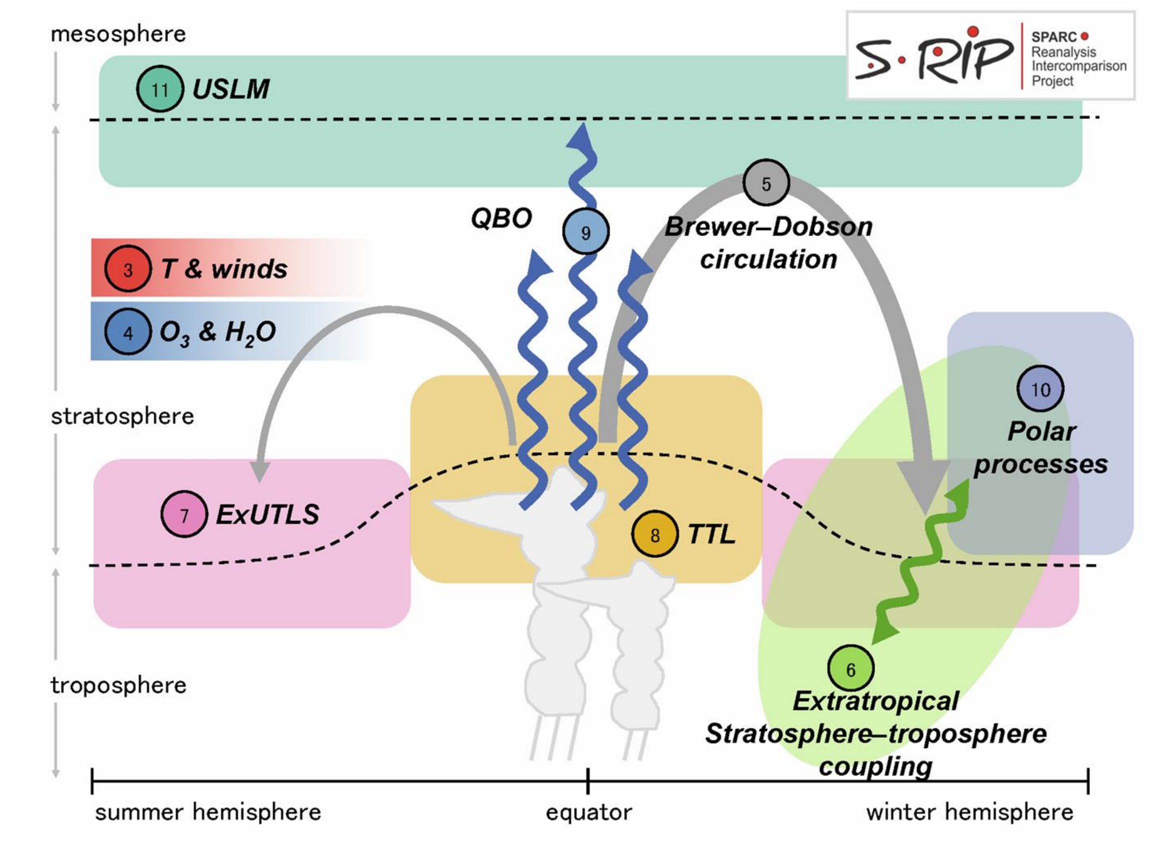


Figure 1: S-RIP chapter schematic.

S-RIP (https://s-rip.ees.hokudai.ac.jp (https://s-rip.ees.hokudai.ac.jp)) is a coordinated WCRP/SPARC-supported activity to:

- Compare reanalysis data sets for key diagnostics.
- Identify and understand the causes of differences amongst reanalyses.
- Provide guidance on the appropriate usage of reanalysis products in scientific studies.
- Establish and foster collaborative links between reanalysis centres and data users.
- Contribute to future improvements in reanalysis products.

The first phase of S-RIP project is nearing completion, with the S-RIP Report in review. See also several journal publications (1) (https://s-rip.ees.hokudai.ac.jp/pubs/index.html) & (2) (https://s-rip.ees.hokudai.ac.jp/pubs/intercomp.html).

	Chapter Title	Chapter Co-leads
1	Introduction	Masatomo Fujiwara, Gloria Manney, Lesley Gray
2	Description of the Reanalysis Systems	Jonathon Wright, Masatomo Fujiwara, Craig Long
3	Overview of Temperature and Winds	Craig Long, Masatomo Fujiwara
4	Overview of Ozone and Water Vapour	Michaela Hegglin, Sean Davis
5	Brewer-Dobson Circulation	Beatriz Monge-Sanz, Thomas Birner
6	Extratropical Stratosphere-Troposphere Coupling	Edwin Gerber, Patrick Martineau
7	Extratropical Upper Tropo. Lower Strato. (UTLS)	Cameron Homeyer, Gloria Manney
8	Tropical Tropopause Layer	Susann Tegtmeier, Kirstin Krüger
9	Quasi-Biennial Oscillation (QBO)	James Anstey, Lesley Gray
10	Polar Processes	Michelle Santee, Alyn Lambert, Gloria Manney
11	Upper Strato. Lower Mesosphere	Lynn Harvey, John Knox
12	Synthesis Summary	M. Fujiwara, G. Manney, L. Gray, J. Wright

Figure 2: S-RIP chapters and lead authors.

The right 3 panels show highlights / key findings from each of the diagnostic chapters (Chapters 3 through 11).

With the current S-RIP project reaching fruition, we are planning "Phase II" of this project to comprehensively evaluate the next generation of reanalyses including ERA5.

HIGHLIGHTS FROM CHAPTERS 3 - 5

Chapcter 3: Overview of Temperature and Winds

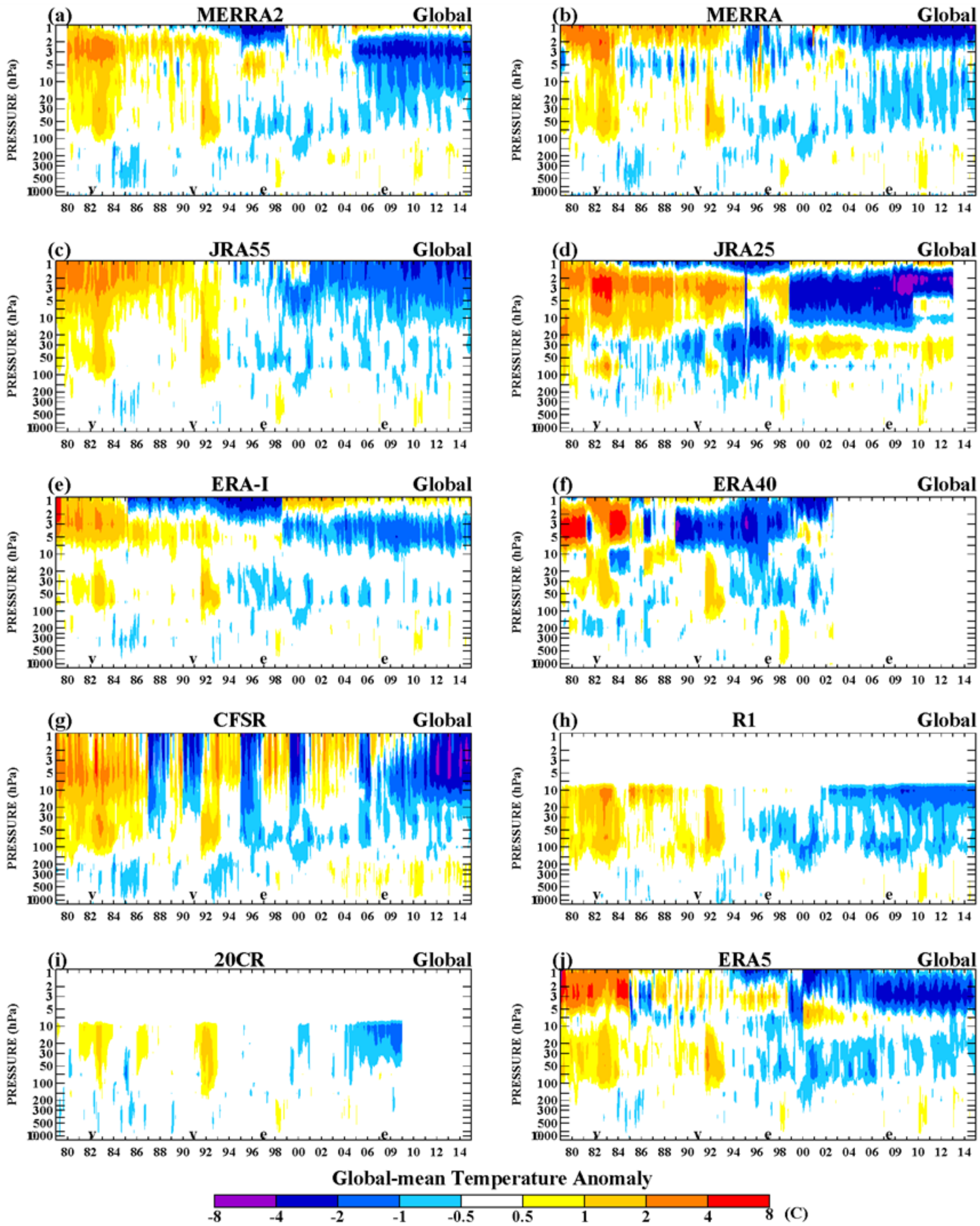


Figure 3: Zonal mean reanalysis temperature differences from a reanalysis ensemble mean (REM).

Key findings include:

- Extreme caution is advised in using reanalyses to estimate trends since irregularities in longterm time series may occur because of changes in available data sources (especially in the upper stratosphere, at pressures below 10 hPa).
- Before 2005 (when GNSS-RO observations were first assimilated), large temperature biases between reanalyses were seen in the UTLS.

Chapter 4: Overview of Ozone and Water Vapour

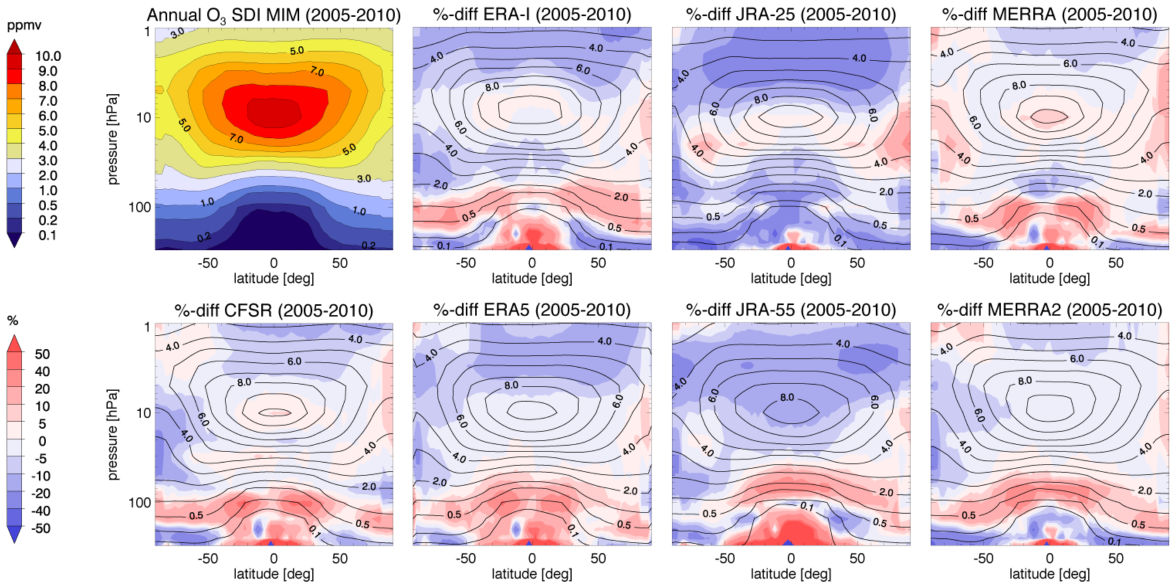


Figure 4: Reanalysis ozone compared with SPARC Data Initiative Climatology.

Key findings include:

- Ozone climatologies, annual cycles, and interannual variability typically agree well with observations.
- Total column ozone is largely captured by reanalyses, with some limitations (e.g., no column ozone data during polar night).
- The ozone vertical distribution is weakly constrained by data assimilation, so mean biases in ozone products vary with height (from 10 to 50% in the stratosphere).
- Stratospheric water vapour products from current reanalyses are generally not recommended for use in scientific studies.

Chapter 5: Brewer-Dobson Circulation

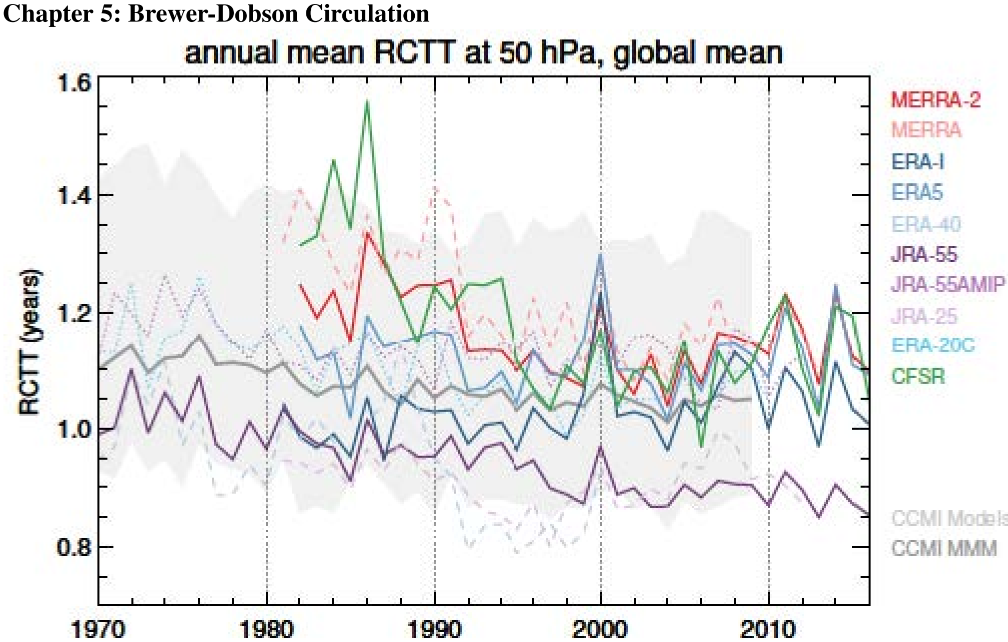


Figure 5: Residual circulation transit time (RCTT) at 50 hPa from reanalyses compared with range from Chemistry Climate Model Initiative models.

Figure 5 shows:

- Overall strengthened BDC at 50 hPa, mostly consistent between models and reanalyses (except for ERA-Interim; CFSR shows questionable variability).
- Robust strengthening of the SH shallow circulation branch (negative RCTT trend in all recent reanalysis products, even in ERA-Interim), but models show very large spread and opposite trend.

HIGHLIGHTS FROM CHAPTERS 6 - 8

Chapter 6: Extratropical Stratosphere-Troposphere Coupling

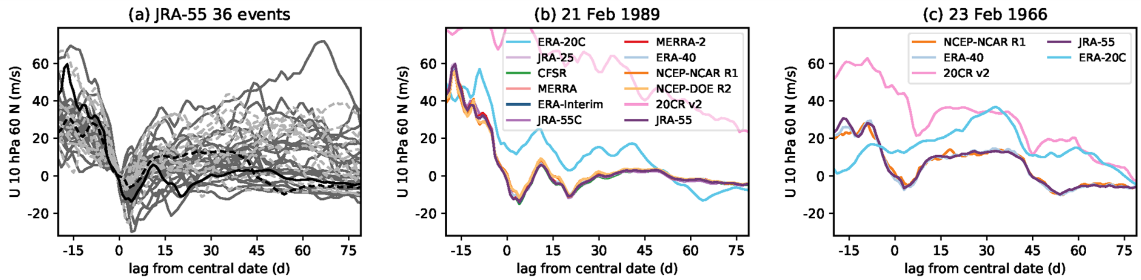


Figure 6: Pre- and post-satellite era Sudden StratosphericWarmings. (a) Winds from JRA-55 for 36 sudden warmings in satellite era (dark grey) and radiosonde era (light grey, dashed lines) and for one (b) satellite-era and one (c) radiosonde era event for all reanalyses (shown as black line solid and dashed lines, respectively, in (a).

Key findings include:

- In satellite era, large scale circulation is very consistent across reanalyses, and uncertainty in S-T coupling is therefore limited by sampling (i.e., by natural variability) (see Gerber & Martineau, 2018).
- Pre-satellite era reanalyses in the NH appear of good quality, and can reduce sampling uncertainty, while pre-satellite era reanalyses in the SH are generally of poor quality (see Hitchcock, 2018).

Chapter 7: Extratropical Upper Troposphere and Lower Stratosphere (UTLS)

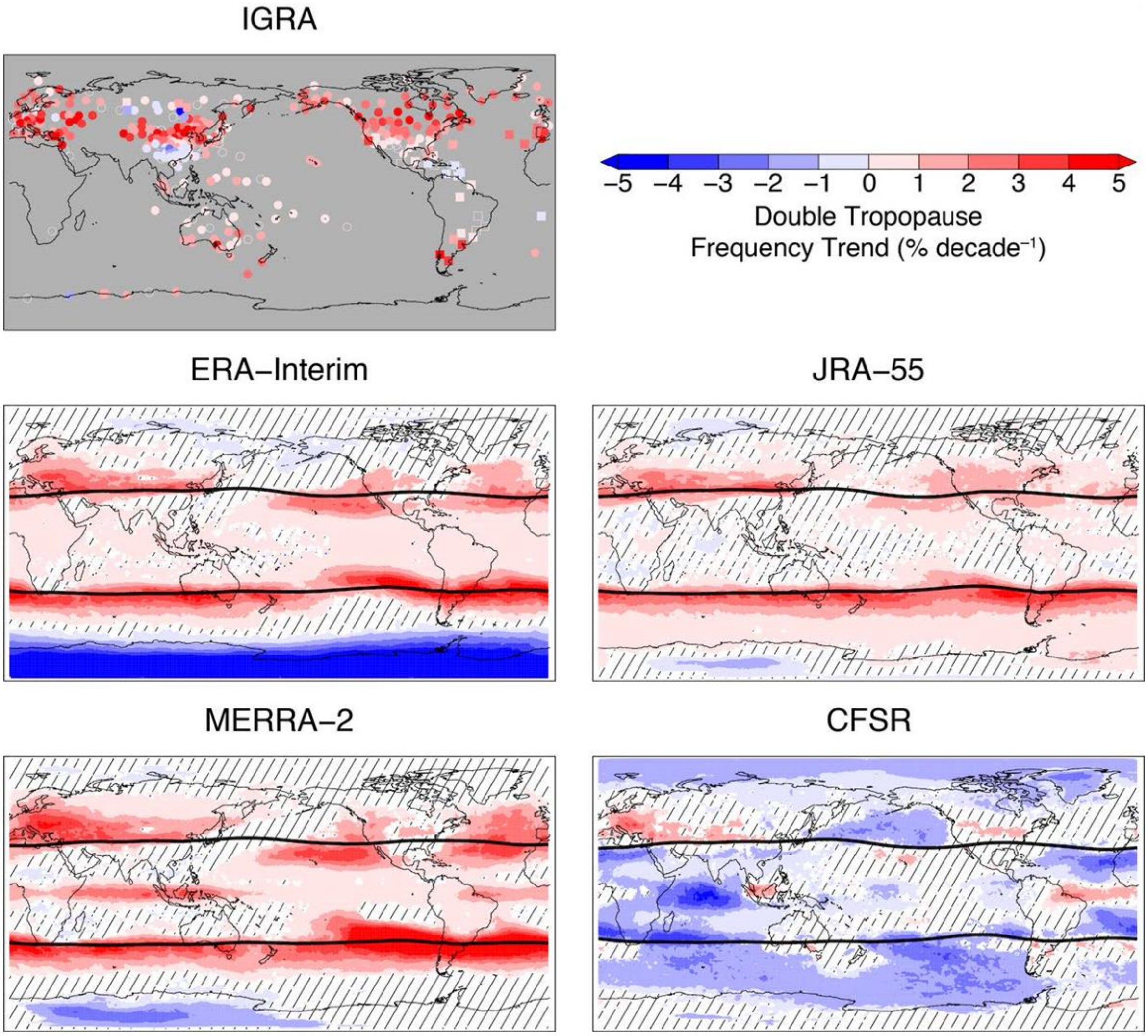


Figure 7: Double tropopause tendencies from radiosonde data and four reanalyses for 1980 through 2015 (Xian & Homeyer, 2018).

Figure 7 shows:

- Double tropopause frequencies have increased during the past 35 years throughout the subtropics and midlatitudes of each hemisphere.
- Most modern reanalyses broadly reproduce patterns of observed trends, but do not capture the extent of poleward expansion of multiple tropopause occurrence.
- Increasing double tropopause frequency indicates more frequent poleward transport of tropical upper tropospheric air into the extratropical lower stratosphere over time.

Chapter 8: Tropical Tropopause Layer (TTL)

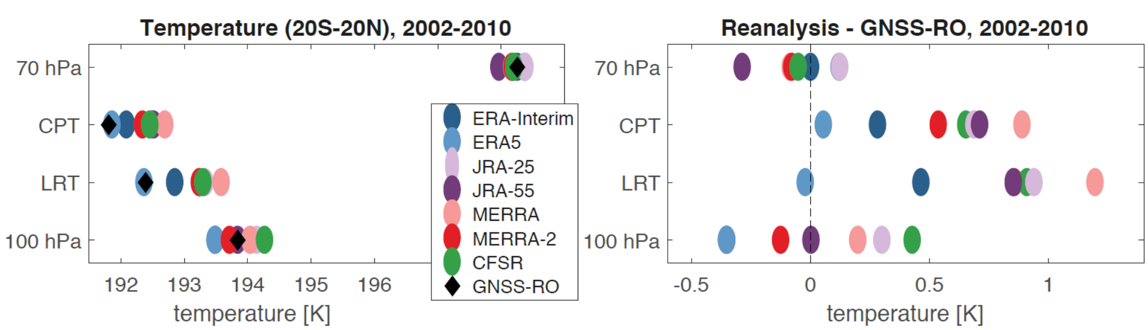


Figure 8: Tropical mean (20S–20N) temperature at 100 hPa, lapse rate tropopause (LRT), cold point tropopause (CPT), and 70 hPa from reanalyses compared to GNSS radio occultation data.

Key findings include:

- Reanalyses provide realistic representations of temperature structure within the TTL.
- Interannual variability in reanalysis temperatures is best constrained in the upper TTL (70 hPa), with larger differences at lower levels such as the cold point and 100 hPa.
- Tropical high cloud fields are substantially different among reanalyses, as are reanalysis diabatic heating products within the TTL.
- Modern reanalyses agree well regarding the climatological position and extent of the South Asian Summer Monsoon (SASM) anticyclone, although there are notable differences in the distribution of SASM anticyclone centre locations among different reanalyses.

HIGHLIGHTS FROM CHAPTERS 9 - 11

Chapter 9: Quasi-Biennial Oscillation (QBO)

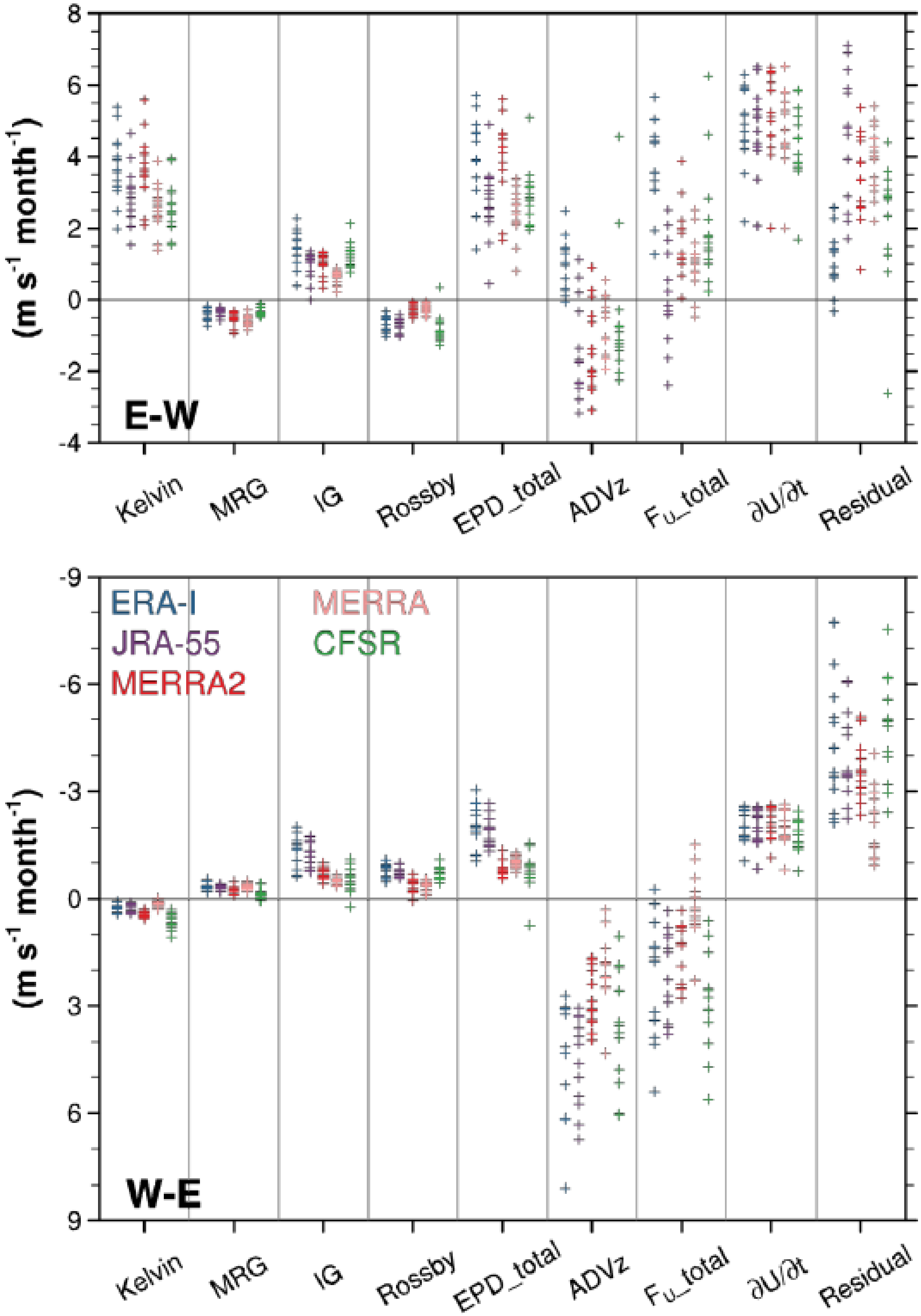


Figure 9: Terms in the QBO zonal-mean zonal momentum budget from 5N to 5S at 30 hPa, averaged over the easterly-to-westerly and westerly-to-easterly transitions during 1981-2010. Note that the y-axis direction is reversed in the bottom panel. See also Kim & Chun (2015).

Figure 9 shows:

- Residual of the momentum budget is large, particularly for easterly QBO onsets.
- Residual includes contributions from small-scale gravity waves not resolved by the reanalyses, which are handled differently in different reanalyses. The nonorographic parameterized wave forcing contributes to the residual in this plot.
- Reanalyses agree fairly well on large-scale wave forcing, mainly because assimilated satellite data provide a constraint on the waves' temperature anomalies.
- Kelvin waves contribute strongly to the westerly onset, and have large natural variability.
- The vertical advection term has large natural variability, and for westerly onsets it has systematic inter-reanalysis sign differences.

Chapter 10: Polar Processes

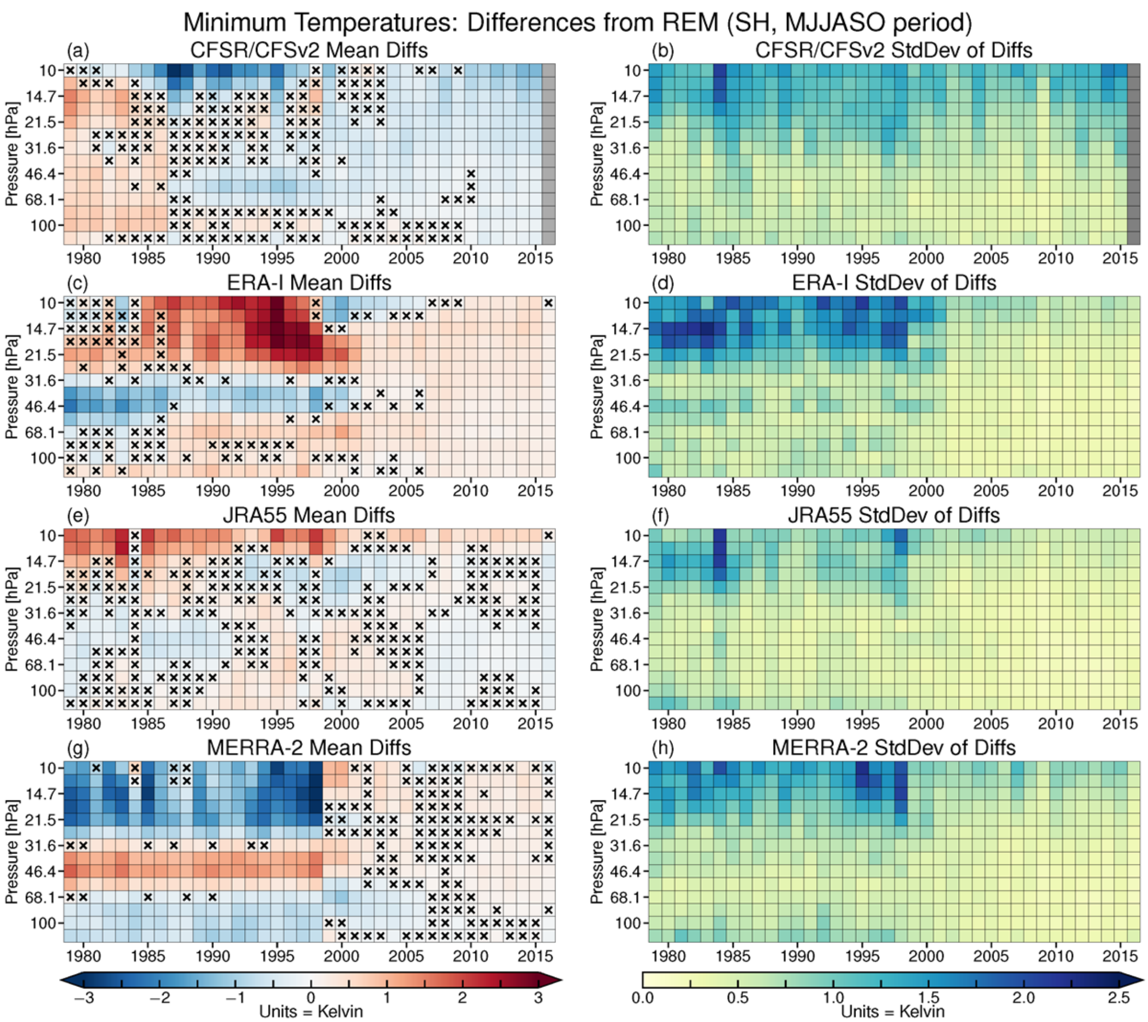


Figure 10: Averages (left) and standard deviations (right) of polar minimum temperature differences for each reanalysis from an REM for the 1979–2015 SH winters. X's indicate differences that are insignificant according to a bootstrapping analysis. See Lawrence et al. (2018).

- The most recent reanalyses show overall much better performance in diagnostics related to lower stratospheric polar chemical processing and ozone loss than older reanalyses (many of which have been shown to be unsuitable for such studies).

Figure 10 shows:

- SH minimum polar temperatures converge towards much better agreement over the period compared.
- A rapid shift towards better agreement is seen around 1999, both in reanalysis differences from the REM and in the standard deviations of the differences.
- This shift is concurrent with changing data inputs from TOVS to ATOVS radiances (providing better vertical resolution in the stratosphere), and is similar to shifts seen in other temperature diagnostics (e.g., see Figure 3).

Chapter 11: Upper Stratosphere and Lower Mesosphere (USLM)

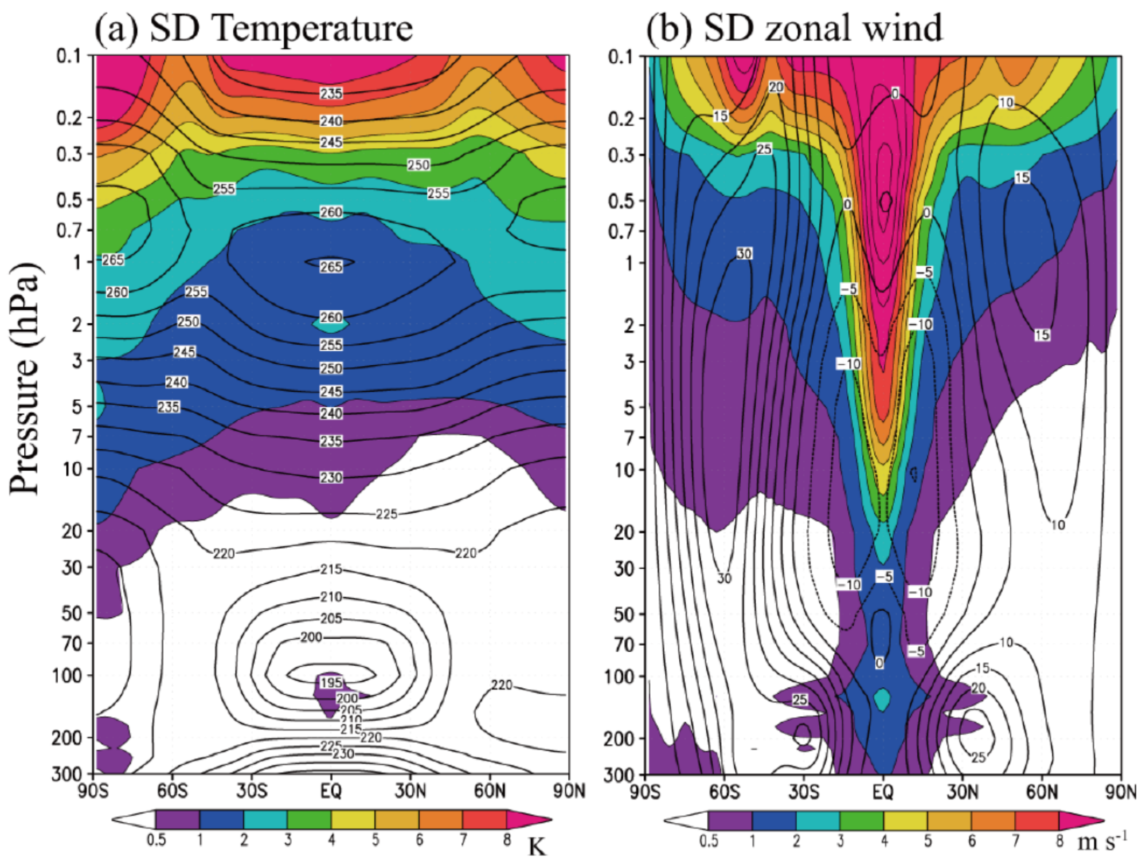


Figure 11: Latitude-altitude distribution of zonal mean and time mean (1980–2012) standard deviations (colors) of (a) temperature and (b) zonal winds for ERA-Interim, JRA-55, MERRA, and MERRA-2. Overlays are annually averaged (a) zonal-mean temperatures and (b) zonal winds (westerlies solid, easterlies dotted). See also Kawatani et al. (2016).

- In the USLM region, reanalyses are generally not very well constrained by the data inputs. Older reanalyses generally either do not extend high enough or
have issues with treatment of the model top, and thus are typically not useful for USLM studies.

Figure 11 shows:

- Differences in temperature (zonal wind) among the reanalyses increase with height into the mesosphere at all latitudes (in the equatorial region).
- Using two or more reanalyses datasets to study phenomena (e.g., the SAO, the diurnal tide) in the tropical USLM region is recommended.
- Scientific studies using reanalyses in the USLM should make every effort to include comparisons with independent observations.

ABSTRACT

The Stratosphere-troposphere Processes And their Role in Climate (SPARC) project is one of the four core projects of the World Climate Research Programme (WCRP). Researchers interested in SPARC use global atmospheric reanalysis products to understand a wide range of processes and variability in the atmosphere, to validate chemistry climate models, and to investigate and identify climate change. The SPARC Reanalysis Intercomparison Project (S-RIP) was initiated in 2011 and officially started in 2013 to conduct a coordinated intercomparison of all major global atmospheric reanalysis data sets. The S-RIP has been aiming at writing up an assessment report in the SPARC report series (to be published by the end of 2020) (1) on overall quality of temperature, winds, ozone, and water vapor data, (2) on more process- and region-oriented evaluation of the Brewer–Dobson circulation, extratropical stratosphere-troposphere coupling, extratropical upper troposphere and lower stratosphere, the tropical tropopause layer, the quasi-biennial oscillation, polar processes, and the upper stratosphere and lower mesosphere, and (3) with a coordinated description of the reanalysis systems. We also have an inter-journal special issue on "The SPARC Reanalysis Intercomparison Project (S-RIP)" in Atmospheric Chemistry and Physics (ACP) and Earth System Science Data (ESSD). In the presentation, we will discuss key findings and recommendations as well as the evaluation of this first phase of the S-RIP activity.