S-RIP SPARC Reanalysis Intercomparison Project

https://s-rip.github.io

SPARC Stratosphere-troposphere Processes And their Role in Climate

S-RIP side/online meeting(s) – Oct-Nov 2022 –

Jonathon S. Wright, Masatomo Fujiwara, and G. L. Manney

(1) Boulder *hybrid*: Thu. 27 Oct. 2022 12:00-13:00 at Boulder, USA (MDT=UTC-6)
[S-RIP side meeting during the SPARC GA]

(2) *Online-only*: Thu. 10 Nov. 4-5 UTC (13-14 JST)

(3) *Online-only*: Thu. 10 Nov. 13-14 UTC (22-23 JST)

Agenda

1. Overview of S-RIP “Phase 1” (M. Fujiwara)

2. Updates from Reanalysis Centers (by Center Reps.)

3. Ideas for S-RIP “Phase 2” (J. S. Wright)

1. S-RIP “Phase 1”

S-RIP SPARC Reanalysis Intercomparison Project

https://s-rip.github.io

- Proposed in 2011; started in 2013
- The goals of S-RIP are:
  - to create a communication platform between SPARC-related researchers and the reanalysis centres
  - to better understand the differences among current reanalysis products and their underlying causes
  - to provide guidance to reanalysis data users by documenting the results of this reanalysis intercomparison in peer reviewed papers and the *SPARC S-RIP Final Report* (January 2022)
  - … with these activities … to contribute to future reanalysis improvements

Table: List of global atmospheric reanalyses evaluated in S-RIP.

Reanalysis Centre (Contacts for S-RIP)	Name of the Reanalysis Products
ECMWF (**R. Dragani**)	ERA-40, **ERA-Interim**, (ERA-20C, ERA-20CM), (CERA-20C), [ERA5 *]
JMA (**Y. Harada, C. Kobayashi**)	JRA-25, **JRA-55** (and JRA-55C, JRA-55AMIP)
NASA (**K. Wargan**)	**MERRA**, **MERRA-2**
NOAA/NCEP (**C. Long, W. Ebisuzaki**)	NCEP-NCAR R-1, NCEP-DOE R-2, **CFSR**
NOAA & Univ. Colorado (**G. Compo, J. Whitaker**)	(20CR)

The S-RIP Planning Meeting (Met Office, UK, 2013)

S-RIP 2018 Chapter-lead Meeting (NWRA, Boulder, USA)

1. S-RIP "Phase 1"

Co-leads: M. Fujiwara, G. Manney, L. Gray

Report Editors: M. Fujiwara, G. Manney, L. Gray, J. Wright

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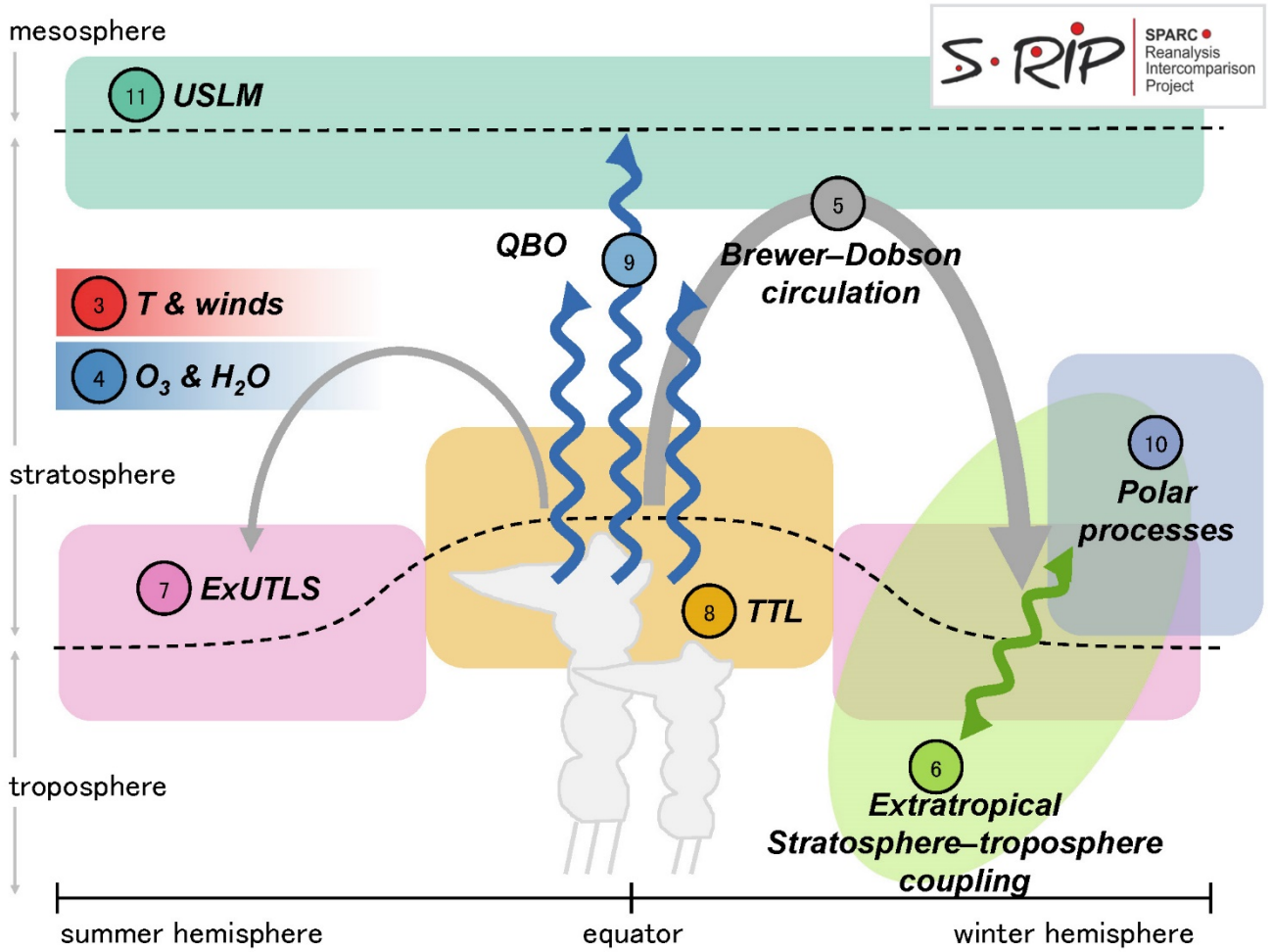
	Chapter Title	Chapter Co-leads
1	Introduction	Masatomo Fujiwara, Gloria Manney, Lesley Gray, Jonathon Wright
2	Description of the Reanalysis Systems	Jonathon Wright, Masatomo Fujiwara, Craig Long
3	Overview of Temperature and Winds	Craig Long, Masatomo Fujiwara
4	Overview of Ozone and Water Vapour	Sean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

(plus ~10 team members for each)



1. S-RIP “Phase 1”

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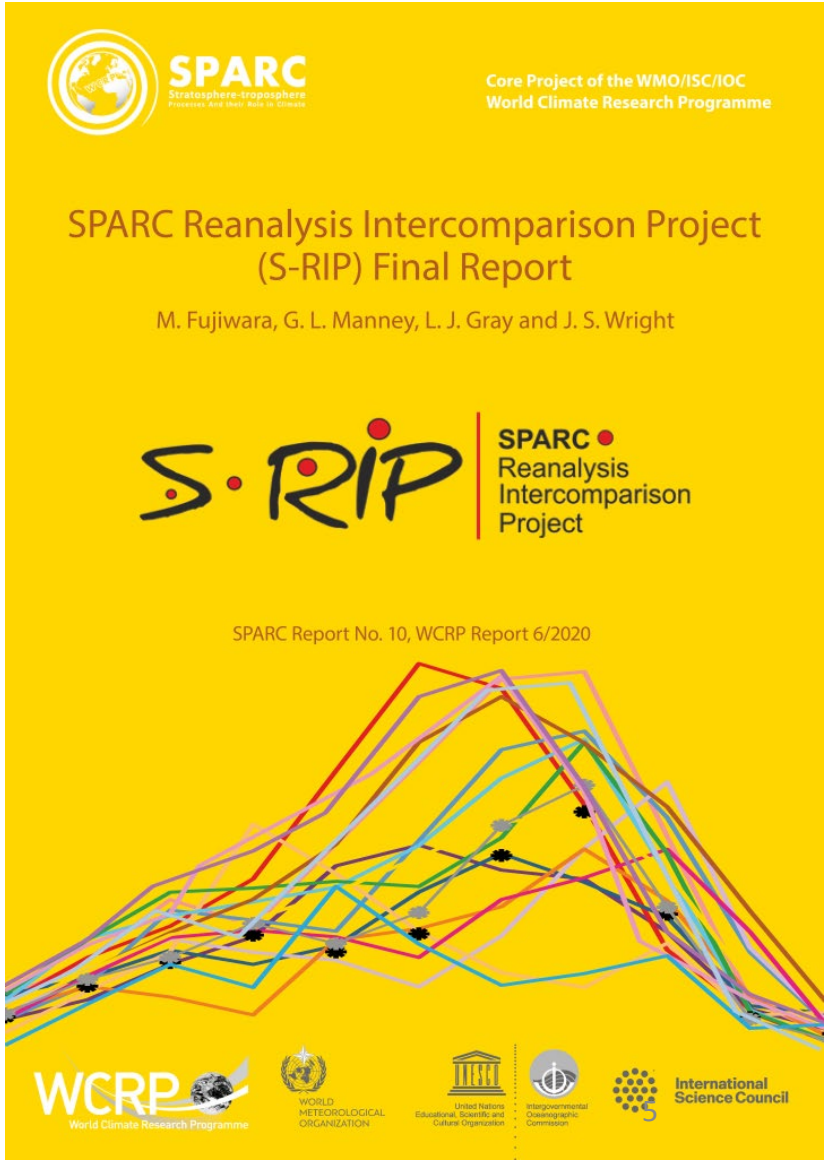
S-RIP Final Report (612 pages, January 2022)

https://www.sparc-climate.org/sparc-report-no-10/



Atmospheric Chemistry and Physics (Open Access, EGU)

Inter-Journal Special Issue on "The SPARC Reanalysis Intercomparison Project (S-RIP)"

Earth System Science Data (Open Access)

- Editors for ACP: P. Haynes, G. P. Stiller, and W. Lahoz
- Editor for ESSD: G. P. Stiller
- Current number of papers: 53
- Deadline: 31 Dec. 2022 [On 1 Jan 2023, we start a new SI on “The S-RIP Phase 2”]

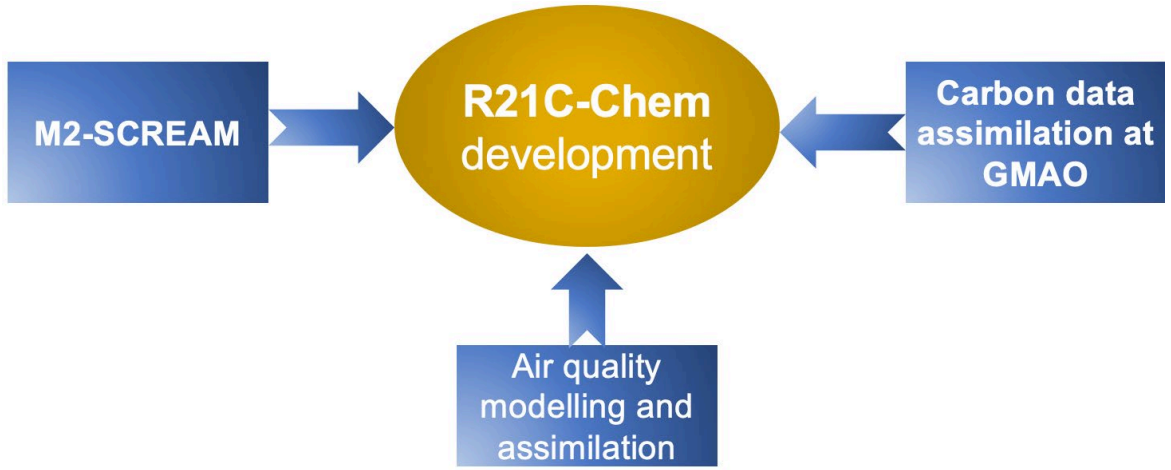
2. Updates from Reanalysis Centers

- NASA GMAO (Kris Wargan)
- NOAA NCEP (Wesley Ebisuzaki, Laura Ciasto)
- JMA (Yuki Kosaka, Yayoi Harada)
- CMA (JSW)
- ECMWF (Hans Hersbach)

R21C: NASA GMAO's Reanalysis of the 21st Century

- **R21C will be a global meteorological reanalysis for 1998–2025** (an extension is possible); the initial two years are spinup
- Assimilation method: **hybrid 4D ensemble Var** (MERRA-2 is 3DVar)
- **The model and assimilation system significantly upgraded since MERRA-2**; R21C will use a recent version of the GEOS Data Assimilation System as implemented in GMAO's current Forward Processing (near real time) analyses;
- **Many new observation types beyond those used in MERRA-2**
- Resolution: **~25 km** (compared to 50 km in MERRA-2), 72 layers (no change)
- Production to start within the next several months
- MERRA-2 will continue to run in parallel
- MERRA-3 (to start ~2027): Coupled atmosphere-ocean reanalysis with a new data assimilation system based on the Joint Effort for Data Assimilation Integration (JEDI) framework

R21C-Chem: Atmospheric Composition Reanalysis



Sensor	Species
OMI, TROPOMI	NO_2, SO_2, O_3
SCIAMACHY, GOSAT, TROPOMI	CH_4
SCIAMACHY, GOSAT, OCO	CO_2
MOPITT TIR & NIR	CO
MLS	O_3, HCl, HNO_3, N_2O, H_2O, CH_3Cl, CO
AIRS, IASI, CrIS FSR	Ozone-sensitive radiances

- Assimilation of selected gases important for **stratospheric and tropospheric chemistry**, with the **Co**nstituent **D**ata **A**ssimilation **S**ystem developed at GMAO
- Meteorology constrained by R21C temperature, winds, surface pressure & tropospheric water vapor
- Model: GEOS GCM with the GEOS-Chem full chemistry module
- Production to start in late 2023 once historical R21C streams are completed

NOAA Reanalyses (NCEP, OAR/PSD)

CORe (Conventional Observation Reanalysis)

Climate reanalysis: designed for climate monitoring and trends more than initial conditions
  Reduce climate shifts by not assimilating satellite obs aside from Atmospheric Motion Vectors
1950-real time when completed
0.7 degree horizontal resolution, 64 vertical levels, cubed sphere model (FV3), GFS physics
3 hour resolution
80 member ensemble, Ensemble Kalman Filtering (EnKF), all members are equally probable

Status
  1950-2021 completed
  Evaluation whether to make it an operational product (¾ done)
  Porting code to operational computer
  Planned 2023 operational system

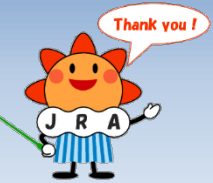
Early Evaluation: expect to make it an operational product
 Trends of CORe, ERA-5 and JRA-55 of many large-scale averages are converging

Seasonal Forecast System Reanalysis

The replacement for CFSR/CFSv2 Needed for statistical post-processing of the future Seasonal Forecast System.

Status
  Model needs to be developed
  Ocean data assimilation needs to be developed
  Atmospheric data assimilation is transitioning to JEDI

Japanese Reanalysis for Three Quarters of a Century (JRA-3Q)



- Reanalysis period: September 1947 to present
- Specifications
  - Resolution: 40 km, 100 layers (in the previous system JRA-55: 55 km, 60 layers)
  - Incorporating a number of improvements from the operational NWP system
    - Overall upgrade of physical processes
    - New types of observation (ground-based GNSS, hyperspectral sounders)
  - Improved SST
    - COBE-SST2 (1-degree, until around 1985) + MGDSST (0.25-degree, from around 1985 onward)
  - Improved observational datasets
    - Observations newly rescued and digitized by ERA-CLIM and other projects
    - Improved satellite observations through reprocessing
    - JMA's own tropical cyclone bogus data
- Progress and schedule
  - August 2019: started production
  - May 2021: completed production for the 1991 – 2020 normal period
  - End of 2022: complete production for the whole period (including rerun from 2013 onwards)
  - Spring 2023: release product for the whole period
    - Details will be announced at the JRA website (https://jra.kishou.go.jp/).

40-year CMA Atmospheric and Land Reanalysis(CRA-40)

CRA-40/Atmosphere

- **Forecast model**: GSM v14
  - T574(~ 34km), top at ~ 0.27 hPa
- **Data assimilation system**: GSI v3.6
  - 3DVar-FGAT, 6-h time window
  - VarBC for satellite radiance and aircraft temperature
- **Observations**
  - Radiosondes & SYNOP: with more Chinese observations
  - Aircraft data from CFSR, Met Office, and NMIC
  - Reprocessed AMV, GPS-RO, scatterometer ocean surface wind
  - Satellite Radiances from CFSR/GDAS
- Production
  - 1979-2018, 4.5year/stream, 6 months overlap between streams

CRA-40/Land

- Forcing data:
  - EnOI based analysis for t, u, v, and q
  - blended precipitation
- Land surface model: Noah v3.6
- No soil data assimilation
- Production
  - 1 stream LSM simulation
  - 1979 - 2018, 6 houly product

Citation:

Liu, Z. Q., L. P. Jiang*, C. X. Shi*, et al., 2022: CRA-40/Atmosphere: The first-generation Chinese Atmospheric Reanalysis (1979–2018): System Description and Performance Evaluation . *J. Meteor. Res. (under review)*

Data: http://data.cma.cn/CRA/

Contact:

Lipeng Jiang (jianglp@cma.gov.cn)

Climate Change

Status of ERA5 and planning for ERA6

Hans Hersbach,

Bill Bell, Paul Berrisford, András Horányi, Joaquin Muñoz Sabater, Julien Nicolas, Paul Poli, Raluca Radu, Dinand Schepers, Adrian Simmons, Cornel Soci, Adrien Oyono Owono, Roberto Ribas, Martin Suttie,

C3S contractors and many others !

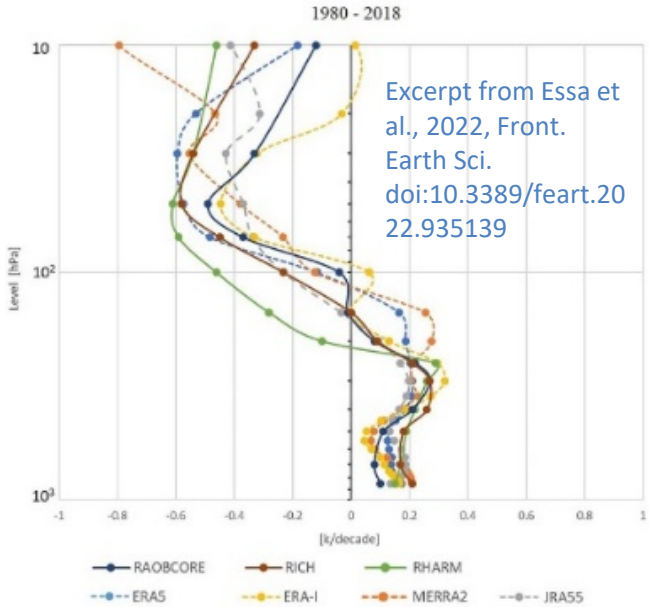
European Commission

ECMWF

Status of the ERA5 global reanalysis

Climate Change

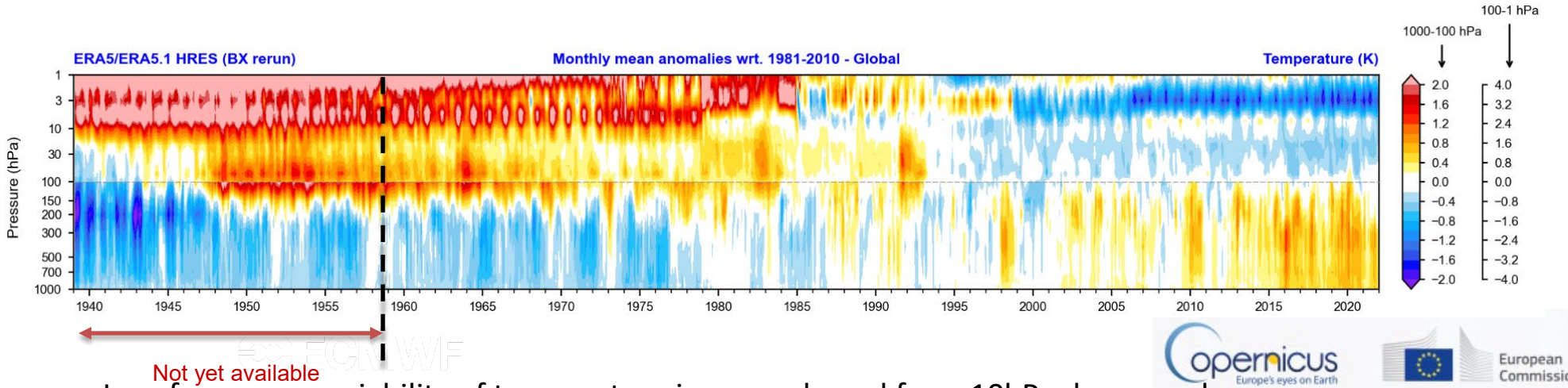
ERA5: *a full-observing-system global reanalysis for hourly gapless snapshots of the atmosphere, land surface and ocean waves at 31km resolution.*



Excerpt from Essa et al., 2022, Front. Earth Sci. doi:10.3389/feart.2022.935139

- Large and diverse user base: 93,000 and growing
- Daily updates 5 days behind real time from 1959 onwards
- ERA5.1 improved mean state of UTLS for 2000-2006
- **Extension back to 1940 recently completed, but not yet publicly available.**
- Assimilated over 100 billion observations, so far
- Ingestion of gridded products, such as SST, SIC, GHGs, aerosols

- 10 hPa downwards in general trustworthy
- But we are aware of a number of known issues



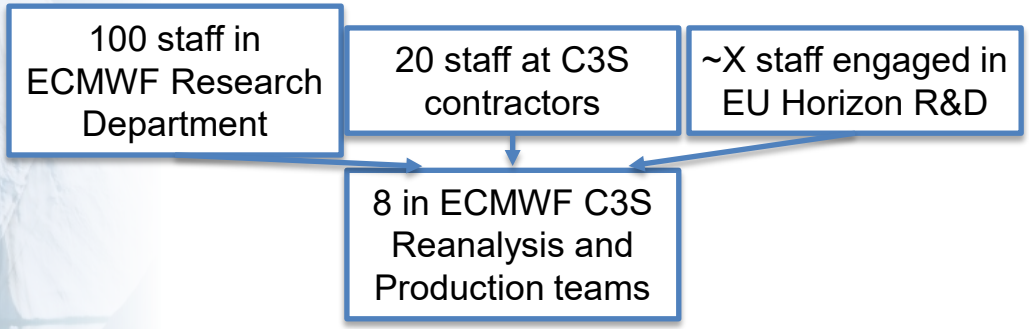
- Low-frequency variability of temperature in general good from 10hPa downwards

Planning for ERA6

Climate Change

ERA6 will benefit from 8 years of R&D at ECMWF & improved compute capacity

Start production : 2024, back extension 2026



- **Improved resolution** (HRES @ 18km or better)
- **Reductions in (free) model bias**
- **Use more & better observations more optimally:**
  - Newly available in IFS since 2016 ERA5 model cycle
  - Reprocessed plus rescued satellite and in-situ from our C3S contractors

- **Improved realism of near-surface quantities and radiative forcing**
  - vegetation cover and type, LAI, lake cover and properties, the urban tile
  - New, and more species of, aerosols and GHG's
- **Improved ocean wave physics**
  - wave physics upgrade
- **4D-Var DA developments**
  - Dynamically evolving climatological part of B
  - Ensemble DA developments
  - WC 4D-Var to counteract model bias
- **Land DA developments**
  - Revised conventional observation feedback for T2m, RH2m and snow analyses
- **Ocean DA developments**
  - ERA6 will be forced by ORAS6 and OCEAN6 fields

Copernicus Europe's eyes on Earth | European Commission | ECMWF

3. S-RIP Phase 2

- Starting now!
- Actual plans depend on participants, but are expected to include:
  - New or unexamined reanalyses (CRA-40, IMDAA/NCMRWF, CERA-20C/CERA-SAT, JRA-3Q, R21C, CORe, …)
  - Reanalyses focused on atmospheric composition (CAMS, BRAM, M2-SCREAM, TCR, R21C-Chem, …) — connections with CCMI, AeroCom, TOAR-II reanalysis activity, etc.
  - New diagnostics or extensions of topics covered in phase 1 (Asian monsoon, Brewer-Dobson circulation variability, polar vortex, lower mesosphere, ozone and water vapor)
  - Additional topical areas not covered in phase 1 (DynVAR / tropospheric disturbances, MJO, teleconnections, …)
  - New tools (ESMValTool, …)
- Leadership changes – **volunteers needed!**
  - New chapter (or topic) leads
  - Plan to rotate in new activity leads

SPARC
Stratosphere-troposphere Processes And their Role in Climate

ccmi
chemistry-climate model initiative

TOAR
tropospheric ozone assessment report

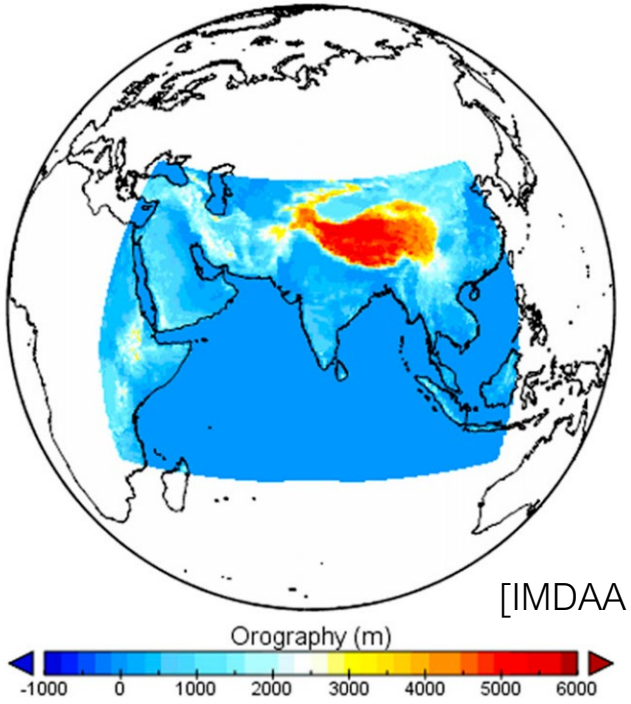
ACAM
ATMOSPHERIC COMPOSITION & THE ASIAN MONSOON

New targets: recently released and upcoming reanalysis products

CRA-40, 20CRv3, JRA-3Q, CORe, R21C, CAFE60?, IMDAA?, …

Reanalysis system	Period	Source	Focus	Horizontal grid	Time
CRA-40	1979 – 2018	China (CMA)	Global atmosphere	~34km (T_L574)	6-hr
CAFE60 (ensemble)	1960 – 2021	Australia (CSIRO)	Global atmos+ocean	2°×2.5°	1-day
IMDAA	1979 – 2020	India (NCMRWF)	Regional atmosphere	12km	1-hr

- New reanalyses from established reanalysis centers
- Several new groups have produced different types of reanalyses in recent years
- Unique focus areas, approaches, and/or data sources suggest new areas for analysis and intercomparison
- We intend to produce systematic documentation as much as possible
- Inclusion in evaluations depends on topic and resources
- Regional reanalyses may also be worth examining for some topical areas



[IMDAA domain]

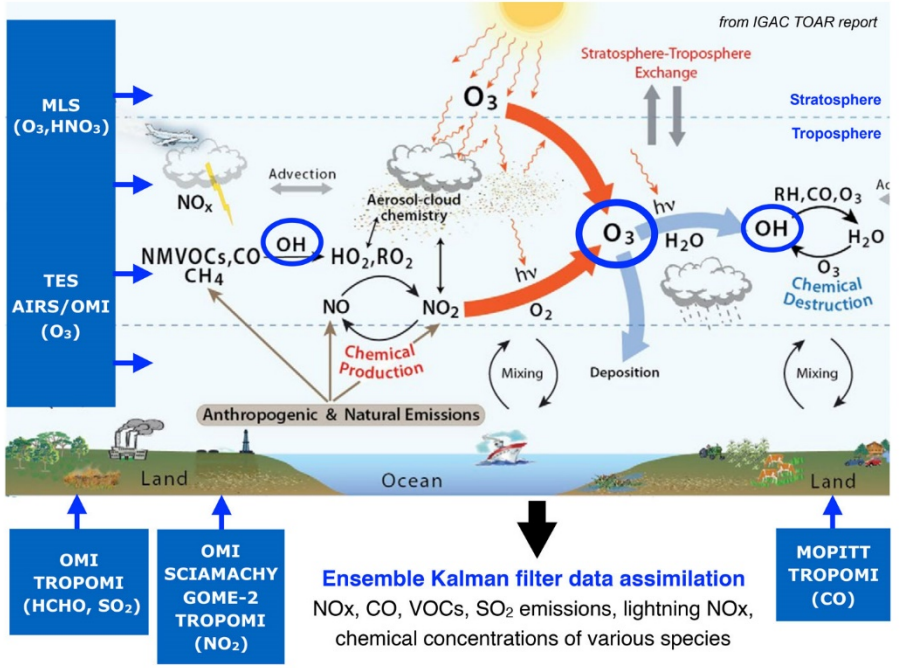
FIG. 1. IMDAA domain with model topography.

New targets: reanalyses of atmospheric composition

CAMS, BRAM, M2-SCREAM, TCR, R21C-Chem, …

Reanalysis system	Period	Source	Focus area	Grid spacing	Levels
CAMS-EAC4	2003 – 2021	ECMWF	Whole atmosphere	0.75°×0.75°	60
BRAM2	2004.09 – 2019.08	BIRA-IASB	Stratosphere	2.5°×3.75°	37
M2-SCREAM	2004.10 – 2021.12	NASA GMAO	Stratosphere	~50km	72
TCR2	2005 – 2019	NASA JPL	Troposphere	T106 (1.1°)	32

- Provides comprehensive information on atmospheric composition variations in troposphere, stratosphere, or both
- Observational information mainly from satellite sensors (O_3, NO_2, CO, HNO_3, SO_2, AOD, …)
- Chemical models of varying complexity
- Some common evaluation frameworks for chemical and meteorological reanalyses?
- Links to CCMI, AeroCom, etc



[TCR2; K. Miyazaki]

The big picture:

Should we be working toward another report?

- Chapter 2 (reanalysis system documentation) to be moved into online format
  - Aim to complement existing efforts such as reanalyses.org
  - Searchable and extendable – new elements can be added as reanalyses incorporate new features
  - Still prioritize consistency of information but with more flexibility and room for expansion
  - Treat as a dataset and apply for a doi to make it citable
- In phase 1, papers in the ACP-ESSD special issue replaced the planned interim report
- Phase 2 to have a new cross-journal special issue including WCD in addition to ACP and ESSD
- With the foundation in place from phase 1, can we focus on building through the special issue?
- Priorities: increase visibility and community awareness of new papers and progress
  - Quarterly webinars inviting one or two papers from the special issue(s) to present?
  - Encourage submissions to workshops organized by other activities / core projects
  - Solicit speakers for S-RIP workshops / webinars from other activities / core projects
- Annual written mini-reports summarizing progress and key results – can this replace a final report?
- Is a formal report needed for reanalyses of atmospheric composition?

The organizing principle:

What topical areas can support a ‘chapter’? Who might lead?

- What does ‘chapter’ mean in this case?
  - Currently thinking of these as coordinated topical areas
  - Chapter/topic leads help to coordinate and summarize progress at regular intervals
- Some continuing or proposed topics so far (far from final!):
  - Polar vortex (builds from Ch10)
  - Stratosphere-troposphere coupling and teleconnections — links to DynVar (builds from Chs 6, 9; many new topics)
  - Upper stratosphere / lower mesosphere (extends Ch11)
  - Stratospheric composition — links to CCMI (builds from Ch4, Chs 7&8)
  - Asian monsoon — links to ACAM and AeroCom (expands Ch8.8)
  - Brewer-Dobson circulation variability and change (builds from Ch5)
  - Representations of surface climate/weather extremes (new topic)
- Evaluations of reanalysis uses, misuses, and recommendations for model evaluation (ESMValTool)
- Form a task team on "web base" – Volunteers?
- Ideas for other/new topics? Volunteers?

More questions for discussion and consideration

- Are there additional recommendations can we make to reanalysis producers at the outset?
- How to deal with the ever-expanding volume of data? Are cloud-based solutions the best/only answer?
- Ideas on pre-processed datasets or diagnostics that could be useful to the community?
- Other activities we should connect or coordinate with?
- Current move toward ‘Earth system’ coupled reanalysis — what role can / should S-RIP play?
- Follow-up online meetings on 10 November at 4UTC (Asia) and 13UTC (Europe) — details at website:

s-rip.github.io

S-RIP

SPARC Reanalysis Intercomparison Project

Contact us:

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Gloria: manney@nwra.com

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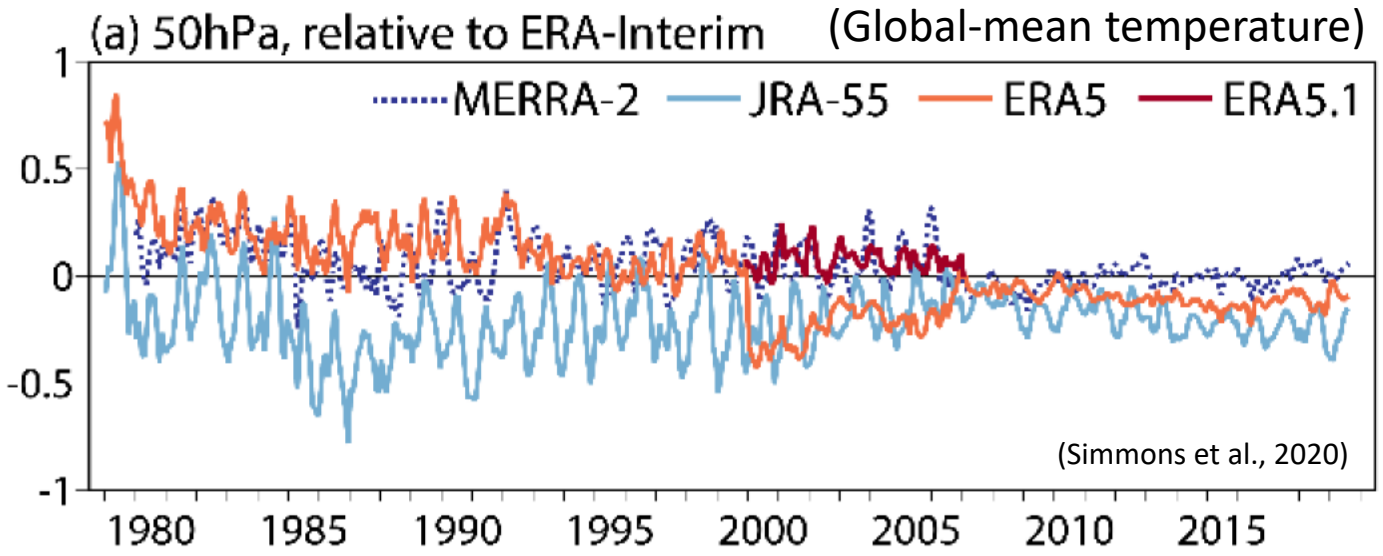
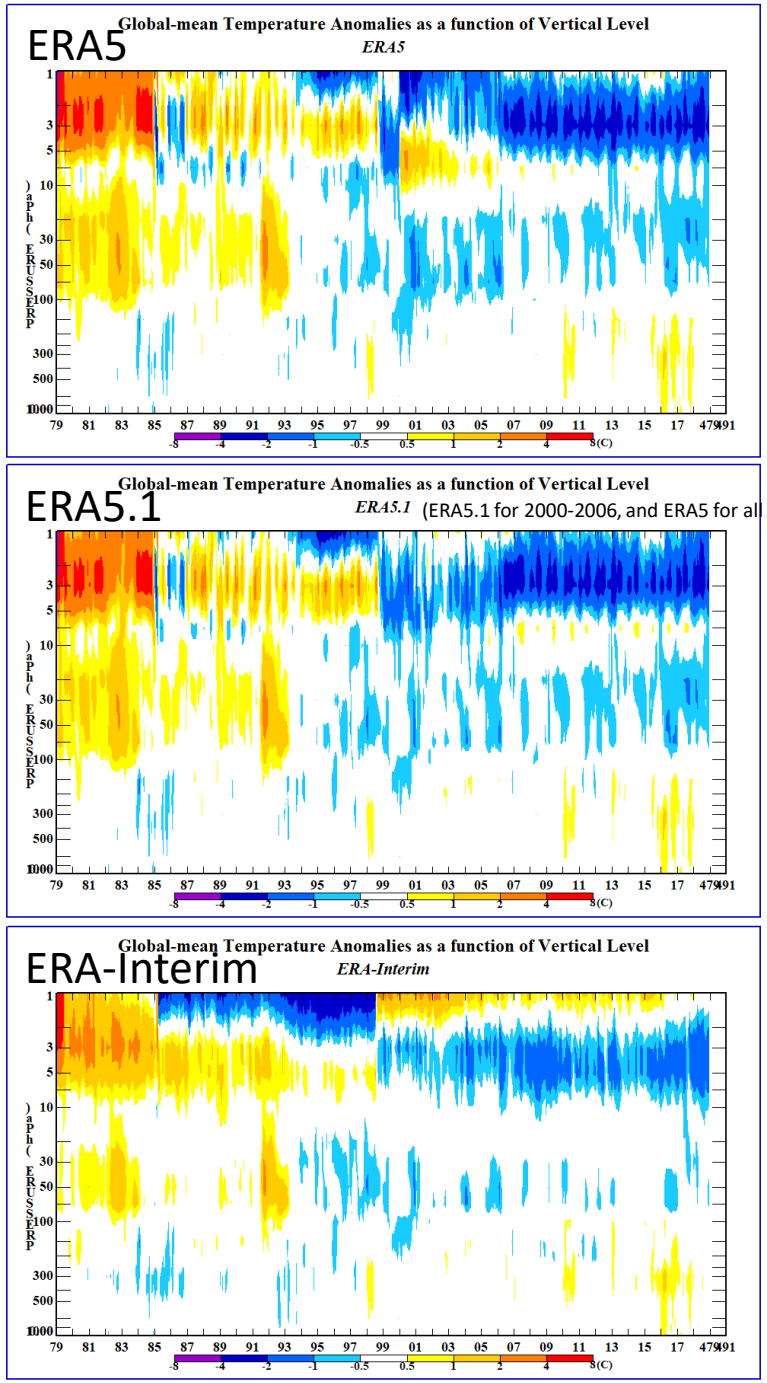
ERA5.1



- ERA5 analyses of lower stratospheric temperature exhibit a pronounced cold bias for the years 2000 to 2006.
- This is due to specifying **background error covariances** for the data assimilation that were inappropriate prior to availability during 2006 of GNSS RO data in sufficient numbers to constrain a cold bias of the assimilating ERA5 model.

- ERA5.1 has thus been produced for the period from 2000 to 2006 using the background error covariances that were used to produce the ERA5 analyses for the years 1979 to 1999.
- ERA5.1 also includes the more restrictive ensemble assimilation of SBUV ozone data that was used in production of ERA5 for 1979 to 1999.

- ERA5.1 provides analyses with better global-mean temperatures in the stratosphere and uppermost troposphere than provided by ERA5.
- ERA5.1 is very close to ERA5 in the lower and middle troposphere.



[Courtesy of Craig Long]

Climate Change

Summary, final remarks

The **ERA5** reanalysis provides **hourly snapshots** of the atmosphere, land surface and ocean waves for **over soon 80 years**

- Very popular dataset on the **CDS**: https://cds.climate.copernicus.eu/#!/home
- We closely monitor the production and quality of ERA5; we know about a number of issues
- Main challenges are related to the strongly evolving observing system

We have started preparations for ERA6:

- Higher resolution and based on an additional 8 years of R&D and state-of-the-art at ECMWF
- Better and more observations; together with C3S contractors
- Address ERA5 challenges:
  - counter-act systematic model error
  - improve the uncertainty estimate
  - further limit discontinuities between production streams

We receive a lot of feedback from our users and listen to them: **we are user-driven**

Further reading:

- ERA5 online documentation
- The ERA5 journal papers (Hersbach et al, 2020, Bell et al., 2021), Simmons et al., 2020, 2021, 2022
- Many, many journal papers.