The APARC Reanalysis Intercomparison Project

Summary of Phase 1 (S-RIP) and Plans for Phase 2 (A-RIP)

Chemical Reanalyses & Air Quality, Tropospheric Circulation, Extreme Events, and More

Jonathon Wright, Gloria Manney, Masatomo Fujiwara, (co-leads)
Sean Davis, Mohamadou Diallo, K. Emma Knowland, Patrick Martineau, Felix Ploeger, Kris Wargan, Brad Weir,
and the S-RIP/A-RIP team (~100 colleagues)

16 April 2024
EGU General Assembly

S-RIP / A-RIP Website

https://s-rip.github.io

Masatomo Fujiwara

Gloria Manney

Jonathon Wright

Phase 1 Final Report

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

Introduction to S-RIP Phase 1

- Active since 2013
- Goals of S-RIP/A-RIP are:
    - establish a communication platform between reanalysis users and producers
    - better understand differences among reanalysis products and their underlying causes
    - provide guidance by documenting system details and intercomparison results
    - contribute to future reanalysis improvements
- Phase 1: focused intercomparison of atmospheric reanalyses in the upper troposphere and above
- ACP/ESSD special issue: 53 papers
- S-RIP Final Report published in January 2022

Table: List of reanalysis systems considered during S-RIP Phase 1.

Reanalysis Centre (contacts for S-RIP)	Name of Reanalysis Product
ECMWF (R. Dragani)	ERA-40, ERA-Interim, ERA5 (ERA-20C, ERA-20CM), (CERA-20C)
JMA (Y. Harada, C. Kobayashi)	JRA-25, JRA-55 (JRA-55C, JRA-55AMIP)
NASA GMAO (K. Wargan)	MERRA, MERRA-2
NOAA/NCEP (C. Long, W. Ebisuzaki)	NCEP-NCAR R1, NCEP-NCAR R2, CFSR
NOAA & U.Colorado (G.Compo, J. Whitaker)	(20CR)

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

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

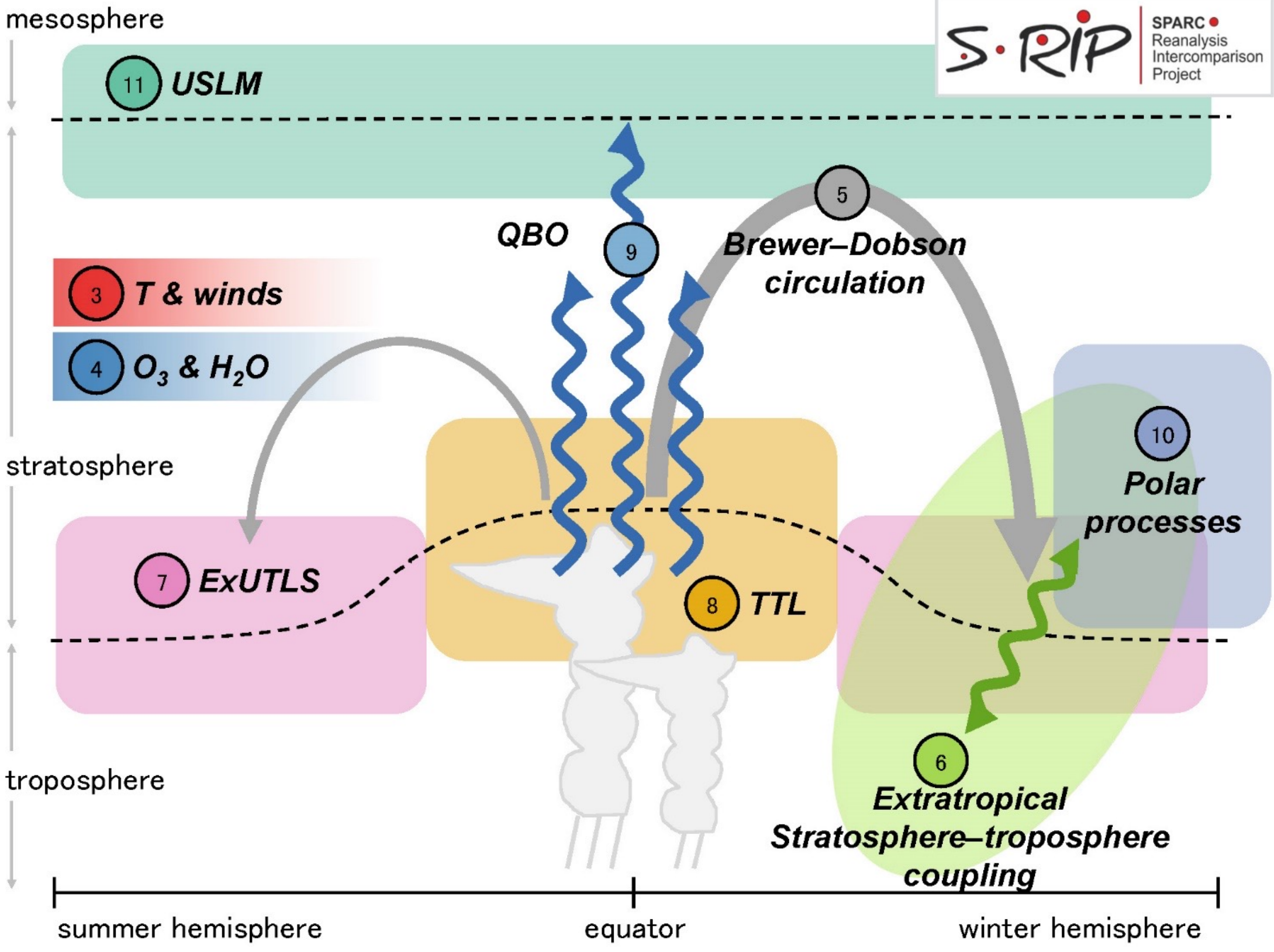
S-RIP Final Report

The S-RIP Report: Content and Structure

Phase 1
Final Report

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

	Chapter Title	Chapter Co-leads
1	Introduction	M. Fujiwara, G. Manney, L. Gray
2	Description of the Reanalysis Systems	J. Wright, M. Fujiwara, C. Long
3	Overview of Temperature and Winds	C. Long, M. Fujiwara
4	Overview of Ozone and Water Vapour	S. Davis, M. Hegglin
5	Brewer-Dobson Circulation	B. Monge-Sanz, T. Birner
6	Extratropical Stratosphere-Troposphere Coupling	E. Gerber, P. Martineau
7	Extratropical Upper Troposphere and Lower Stratosphere (UTLS)	C. Homeyer, G. Manney
8	Tropical Tropopause Layer	S. Tegtmeier, K. Krüger
9	Quasi-Biennial Oscillation (QBO)	J. Anstey, L. Gray
10	Polar Processes	M. Santee, A. Lambert, G. Manney
11	Upper Stratosphere and Lower Mesosphere	L. Harvey, J. Knox
12	Synthesis Summary	M. Fujiwara, G. Manney, L. Gray, J. Wright

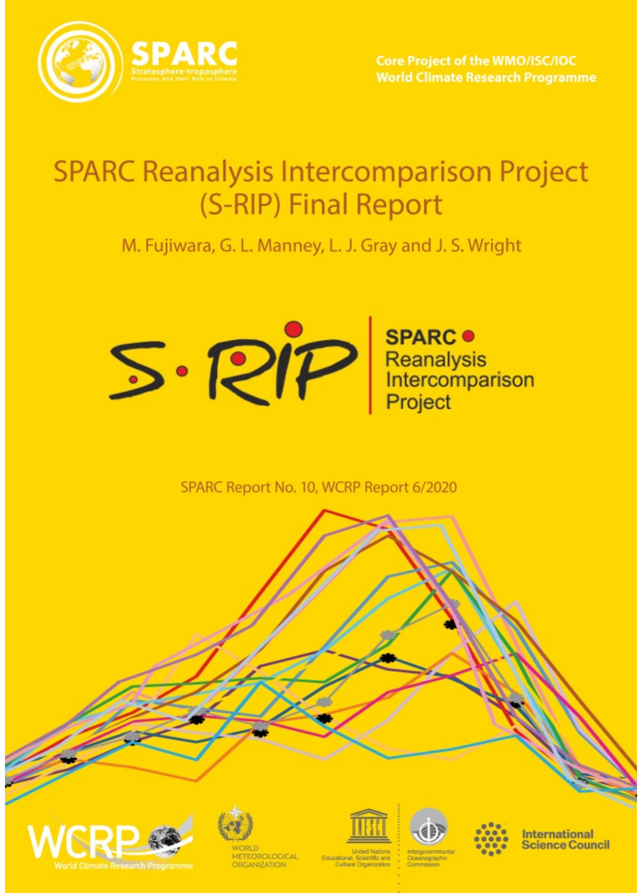


S-RIP Phase 1: 2013-2022

Summary findings and recommendations

- More recent reanalyses typically outperform earlier products
- NCEP-NCAR R1 and NCEP-DOE R2 are unsuitable for many diagnostics and should generally not be used
- Conventional-input and pre-satellite reanalyses are useful for many diagnostics but should be carefully validated against full-input satellite era products
- Studies relying on reanalysis products should use multiple reanalyses whenever possible
- All reanalyses show discontinuities (especially CFSR); trends and climate shifts identified in reanalysis products should be carefully validated and justified
- Reanalysis products on model levels should be used for all studies when sharp vertical gradients or fine-scale vertical features are involved
- Several quantities, such as tendency terms, are handled and reported differently by different reanalyses
- Homogenized and continuing data records are essential for reanalysis production and evaluation

- Coordinated intercomparison and systematic documentation
- Guidance and recommendations for reanalysis users and producers
- 12 chapters totaling ~600 pages

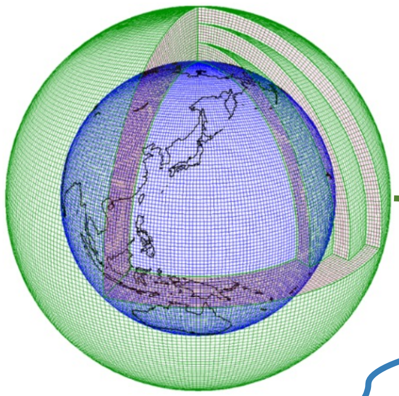


https://www.sparc-climate.org/sparc-report-no-10/

What is an atmospheric reanalysis? A best guess of the past state

- A global atmospheric reanalysis system consists of:
  - A global forecast model (i.e., AGCM) – fixed over time
  - An assimilation scheme (e.g., 3D-Var, 4D-Var, EnKF) – fixed over time
  - Various input observations (radiosonde, satellite radiances, etc.) – quality and quantity vary over time
- Used for studies of weather and climate processes, validation/nudging of GCMs or CCMs, etc.

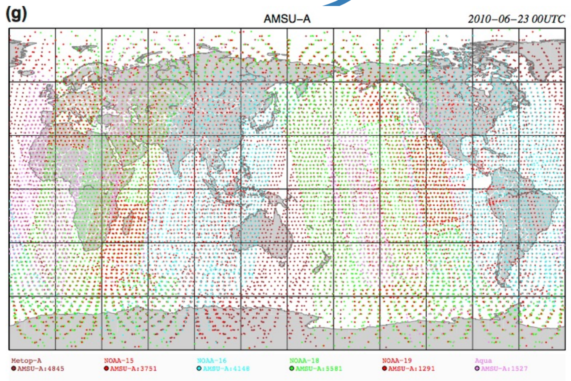
Although atmospheric reanalyses include observations, they are not observations!

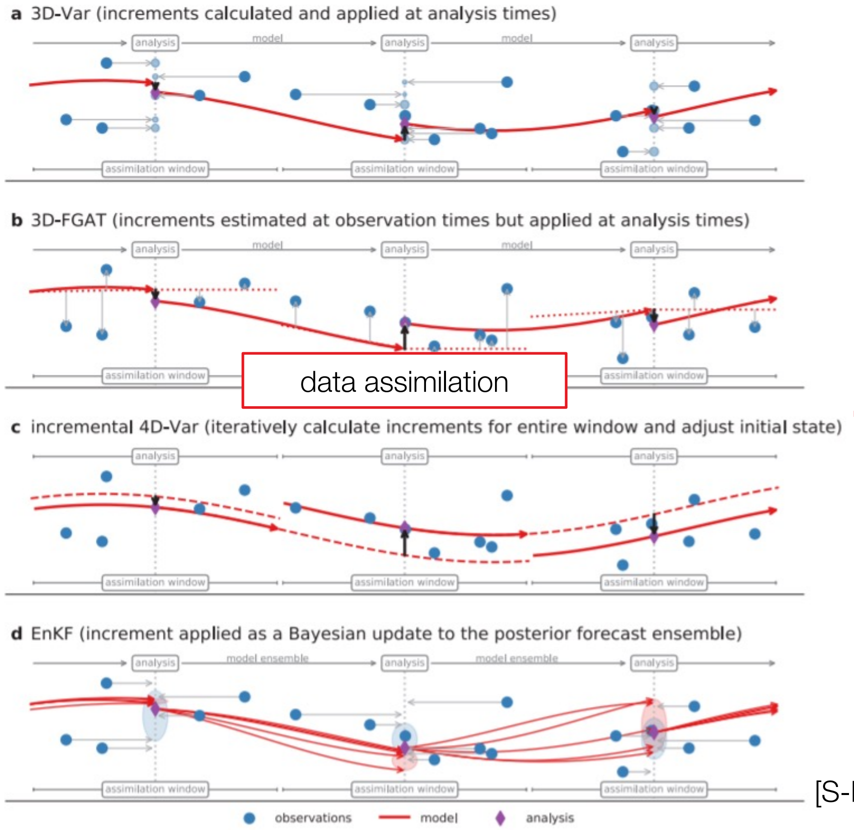


global forecast model

observations

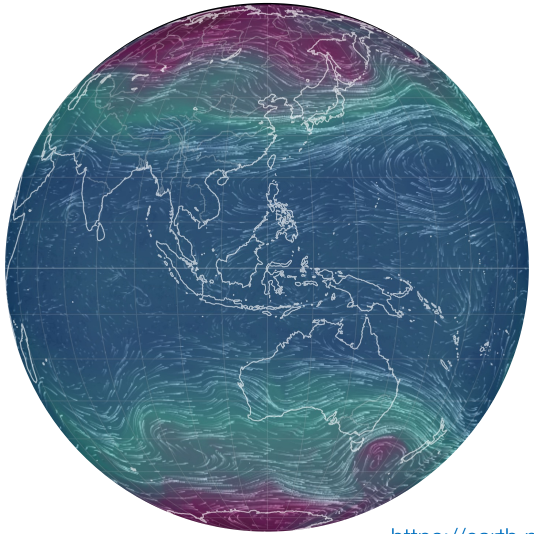
[Fig 2.9]





[S-RIP Chapter 2, Fig 2.6]

analysis

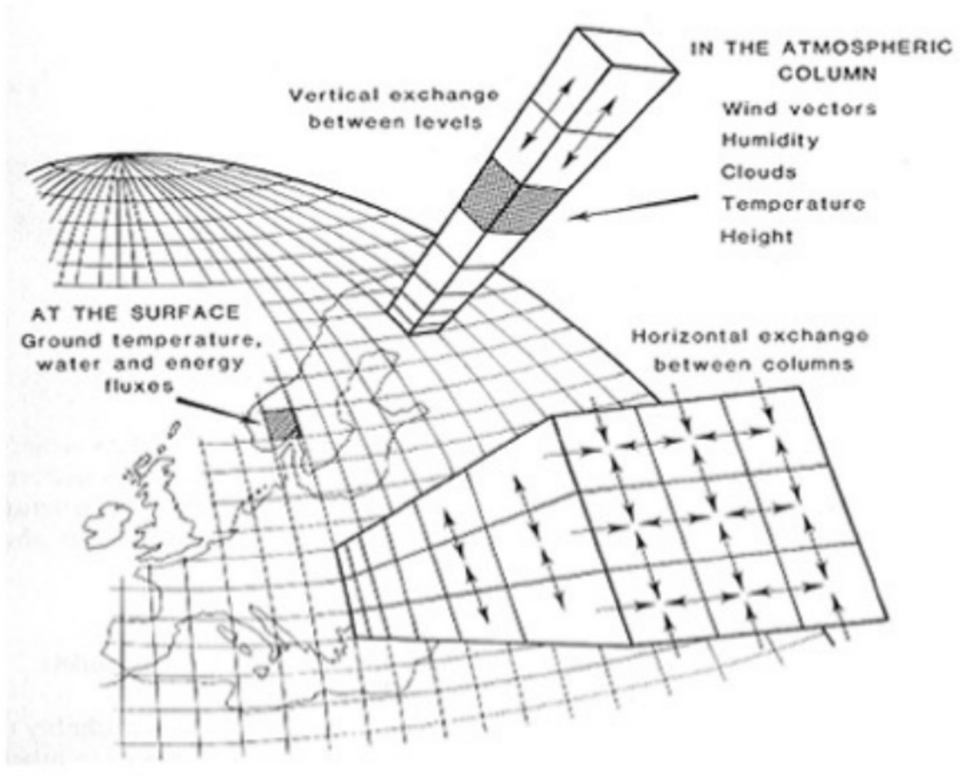


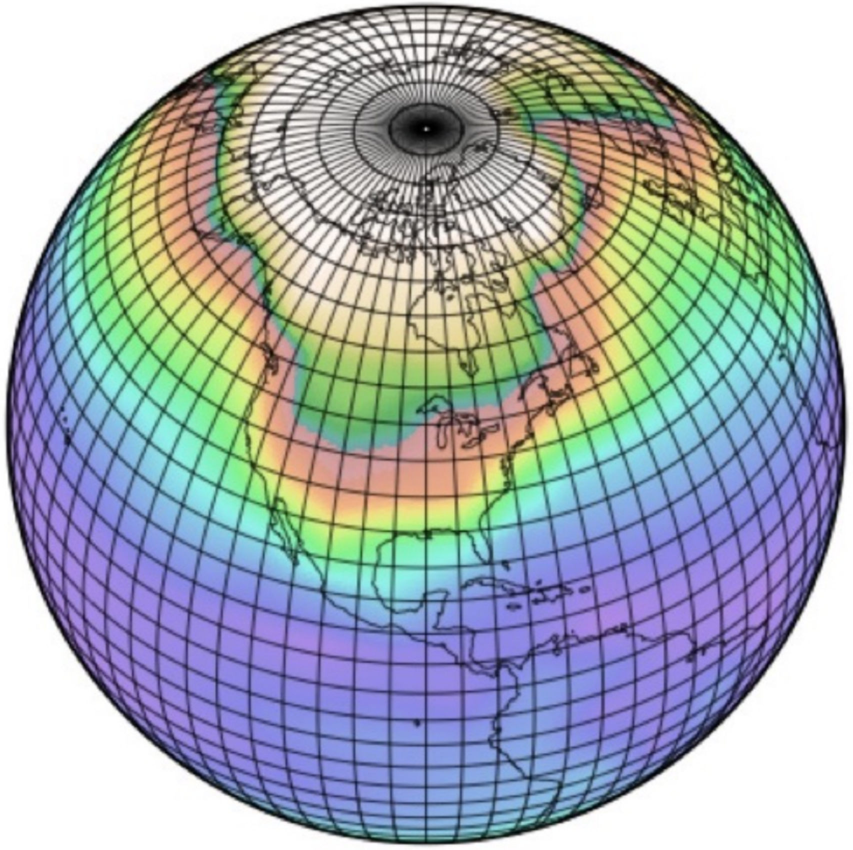
https://earth.nullschool.net

What is an Atmospheric Reanalysis?

Component 1: a global atmospheric model

- Usually a well-tested earlier version of an operational weather forecast model
- The version of the model is fixed over the lifetime of the reanalysis





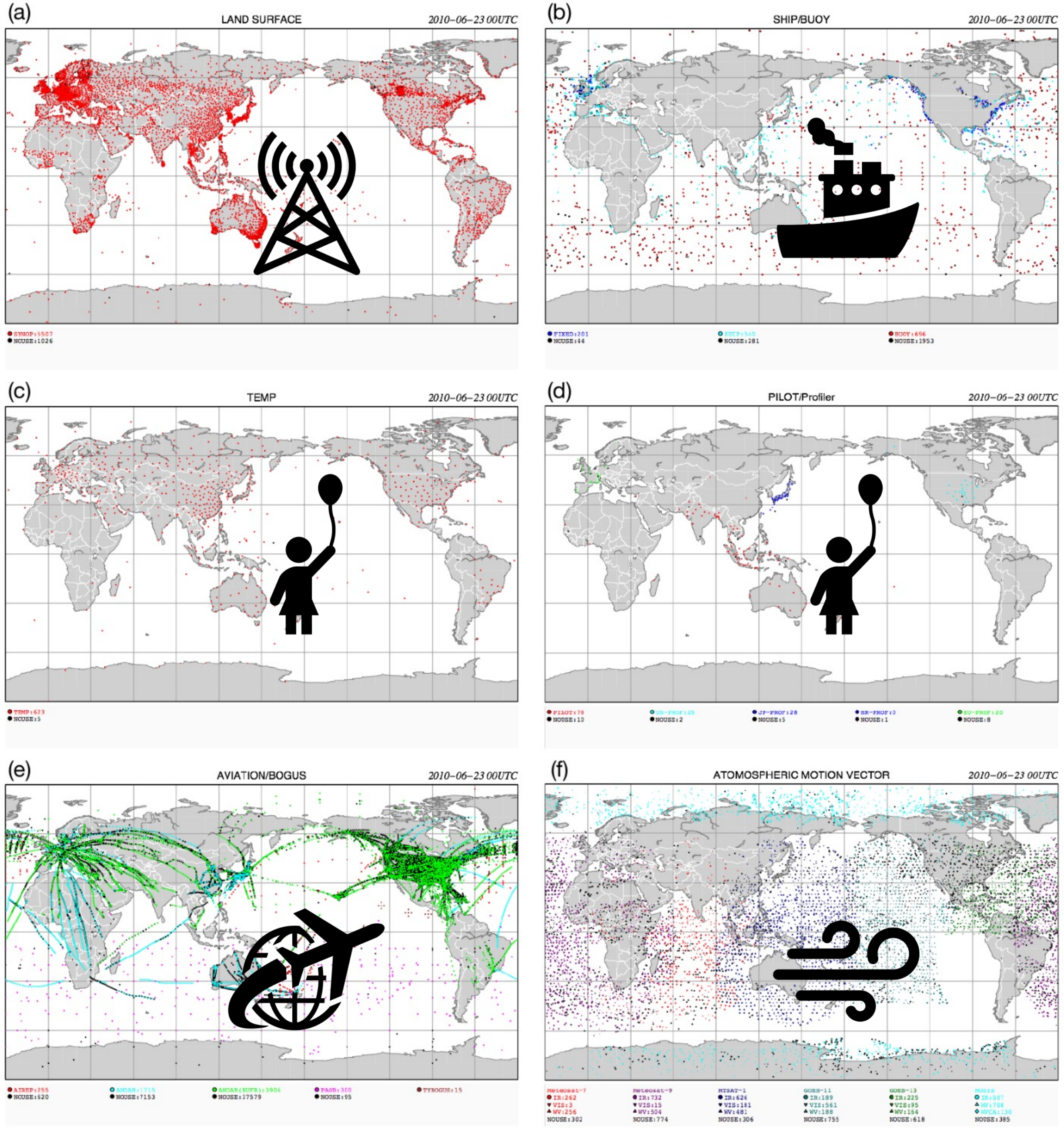
- Consists of several essential components:
  - Grid and dynamical core
  - Physical parameterizations (clouds, convection, radiation, turbulence)
  - Prescribed forcings and boundary conditions
  - Coupled land surface model
- May be coupled to wave or ocean model

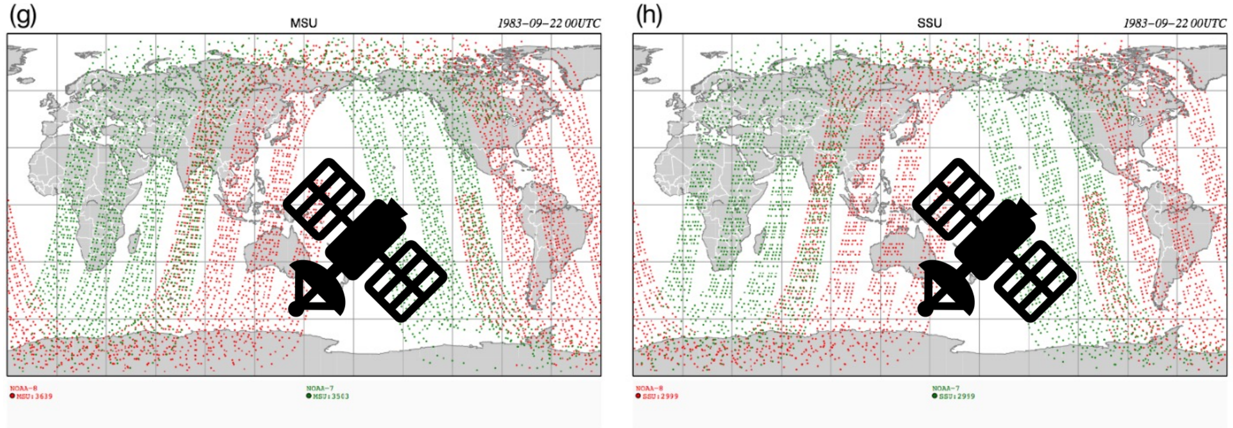
What is an Atmospheric Reanalysis?

Component 2: input observations

[S-RIP Chapter 2, Figs 2.8 & 2.9]

- Reanalyses can be classified by inputs:
  - **Surface input**: surface pressure and winds
  - **Conventional input**: adds radiosondes and aircraft
  - **Full input**: includes satellite data
- Quality and quantity vary in space and time
- Assimilation space is often not variable space!
- Temperature and moisture are constrained by radiances and direct measurements
- Winds are constrained by balance constraints (e.g., thermal wind) and satellite image 'feature tracking' algorithms

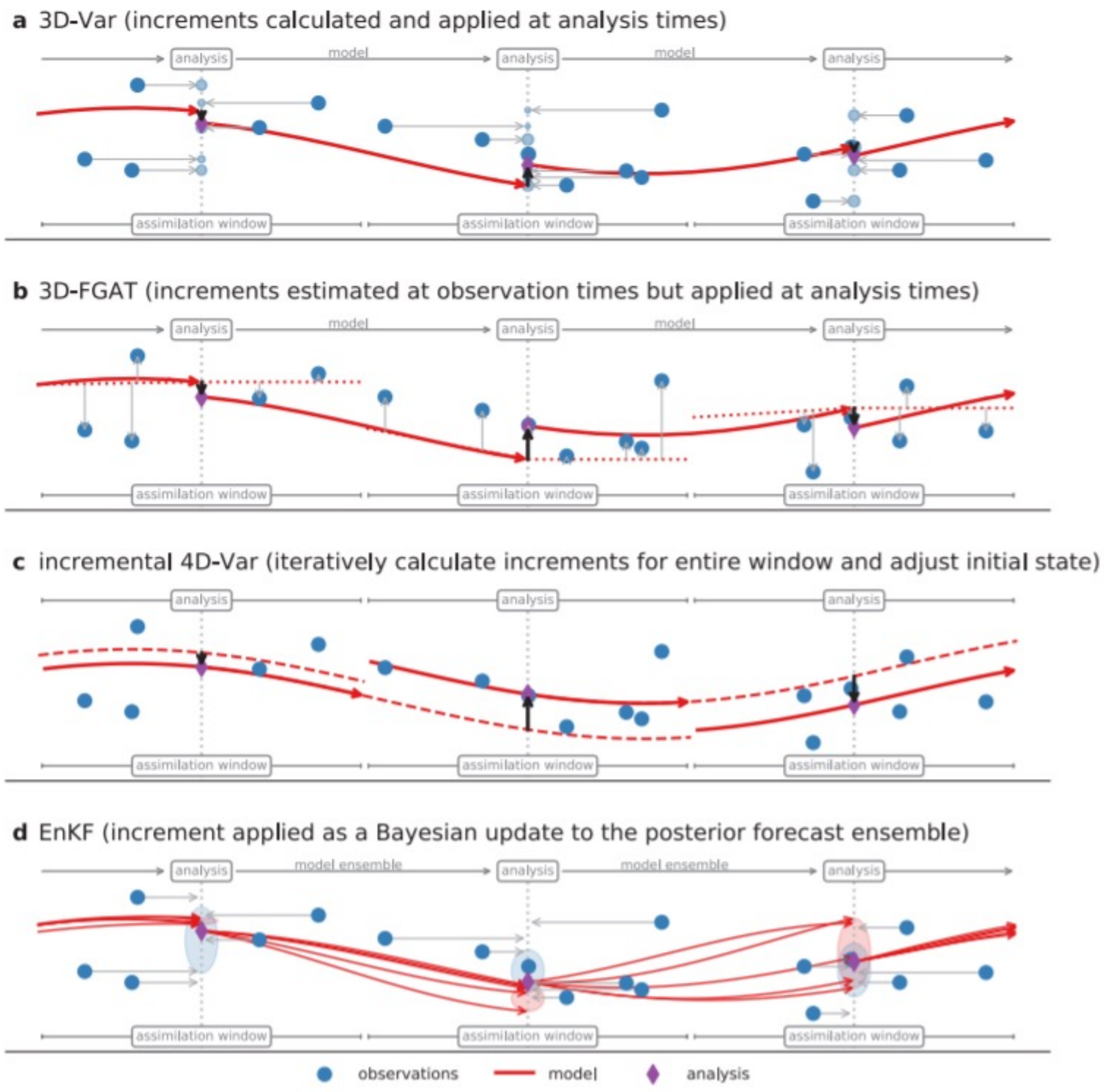




What is an Atmospheric Reanalysis?

Component 3: a data assimilation scheme

- Several strategies illustrated at right:
  - **3D-Var:** JRA-25
  - **3D-FGAT:** NCEP-NCAR, ERA-40, CFSR, CRA-40
  - **3D-FGAT+IAU:** MERRA, MERRA-2
  - **4D-Var:** ERA-Interim, ERA5, JRA-55
  - **EnKF:** 20CR
- Assimilation system is fixed over the lifetime of the reanalysis
- Assimilation combines the model and observed states, accounting for uncertainties in both
- Only a few variables (temperature, humidity, winds) are directly impacted by assimilation
- Other variables (e.g., cloud fields, precipitation) are indirectly impacted through T, q, winds
- Time/space decorrelation scales are important
- Assimilation strategies for upper air and surface air are typically separate



[S-RIP Chapter 2, Fig 2.6]

Chapter 2: Description of the Reanalysis Systems
(Wright et al., SPARC Report No.10, 2022)

An introduction for new users and a reference for experienced users:
Chapter 2 should be helpful for anyone using reanalysis products!

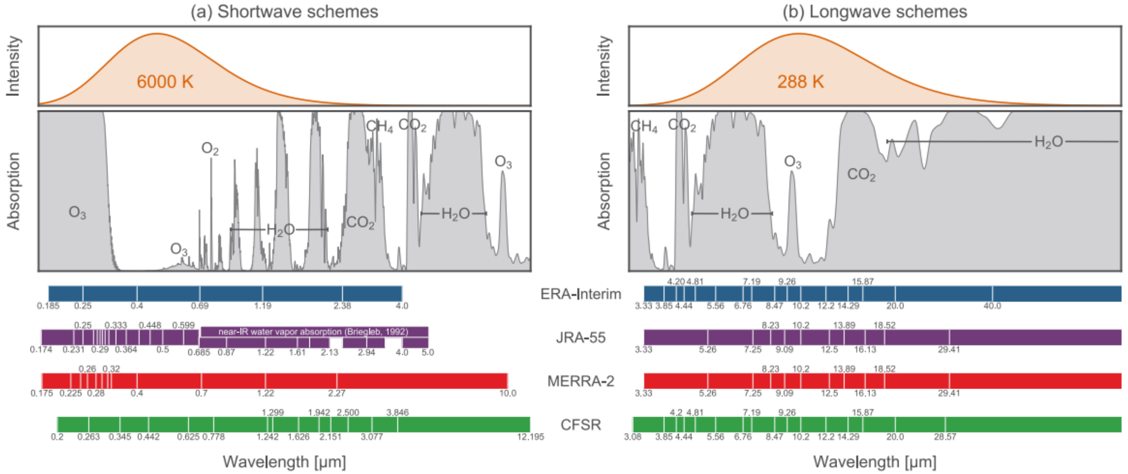
Information on key components of 12 global atmospheric reanalysis systems is summarized, including:
- the forecast models and their major components
- assimilation schemes
- observational data
- execution streams
- archived data products

Now working on an online repository for this information for increased flexibility as new reanalyses are released.

[S-RIP Chapter 2, Table 2.2]

***Table 2.2:** Basic details of the forecast models used in the reanalyses. Horizontal grid spacing is expressed in degrees for regular grids and in kilometres for reduced grids.*

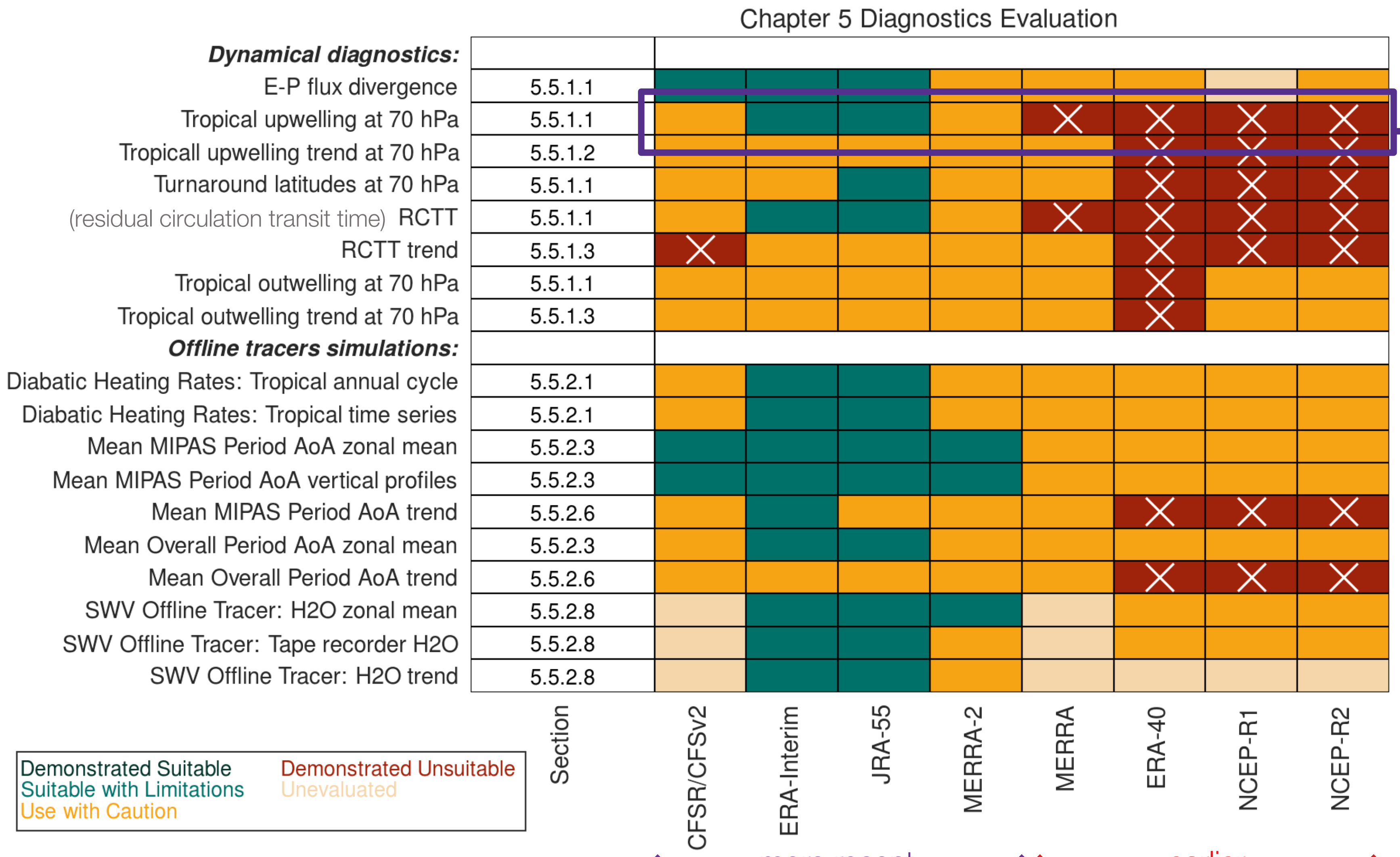
Reanalysis system	Model	Horizontal grid	Vertical grid
ERA-40	IFS Cycle 23r4 (2001)	N80: ~125 km (TL159)	60 (hybrid σ–p)
ERA-Interim	IFS Cycle 31r2 (2007)	N128: ~79 km (TL255)	60 (hybrid σ–p)
ERA-20C	IFS Cycle 38r1 (2012)	N80: ~125 km (TL159)	91 (hybrid σ–p)
ERA5	IFS Cycle 41r2 (2016)	N320: ~31 km (TL639)	137 (hybrid σ–p)
JRA-25 / JCDAS	JMA GSM (2004)	F80: 1.125°(T106)	40 (hybrid σ–p)
JRA-55	JMA GSM (2009)	N160: ~55 km (TL319)	60 (hybrid σ–p)
MERRA	GEOS 5.0.2 (2008)	1/2° latitude, 2/3° longitude	72 (hybrid σ–p)
MERRA-2	GEOS 5.12.4 (2015)	C180: ~50 km (cubed sphere)	72 (hybrid σ–p)
NCEP-NCAR R1	NCEP MRF (1995)	F47: 1.875° (T62)	28 (σ)
NCEP-DOE R2	Modified MRF (1998)	F47: 1.875° (T62)	28 (σ)
CFSR **CFSv2**	NCEP CFS (2007) NCEP CFS (2011)	F288: 0.3125° (T382) F440: 0.2045° (T574)	64 (hybrid σ–p) 64 (hybrid σ–p)
NOAA-CIRES 20CR v2	NCEP GFS (2008)	F47: 1.875° (T62)	28 (hybrid σ–p)

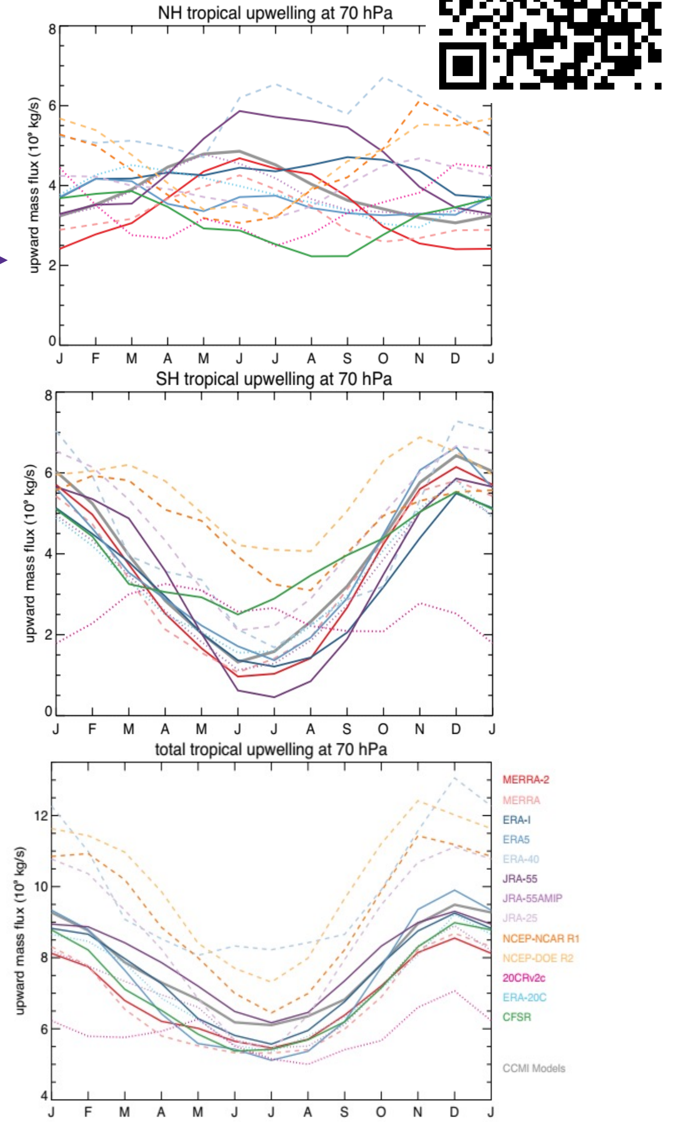


[S-RIP Chapter 2, Fig 2.6]

S-RIP: Key Findings and Recommendations

More recent reanalyses typically outperform earlier products





more recent → earlier

[S-RIP Chapter 5: Brewer-Dobson circulation]

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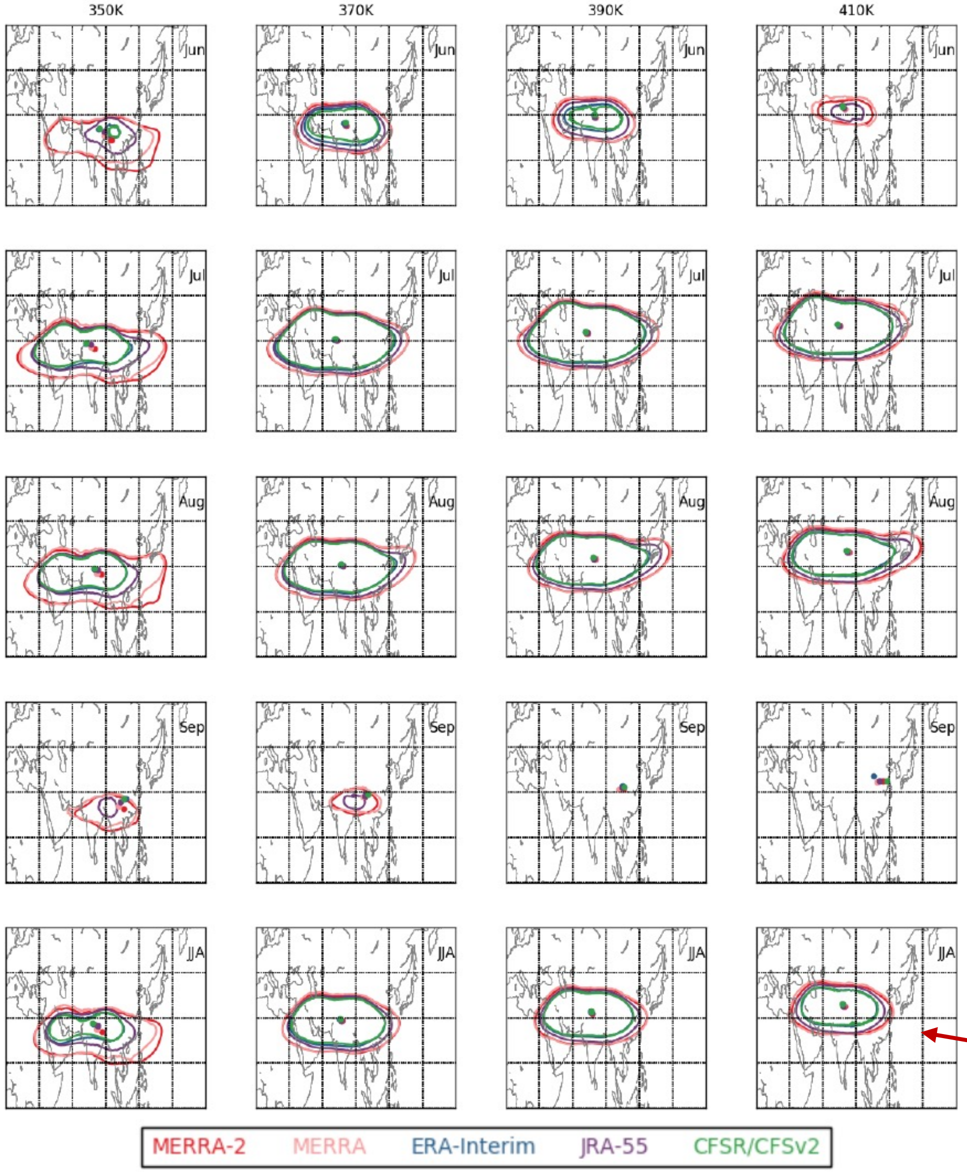
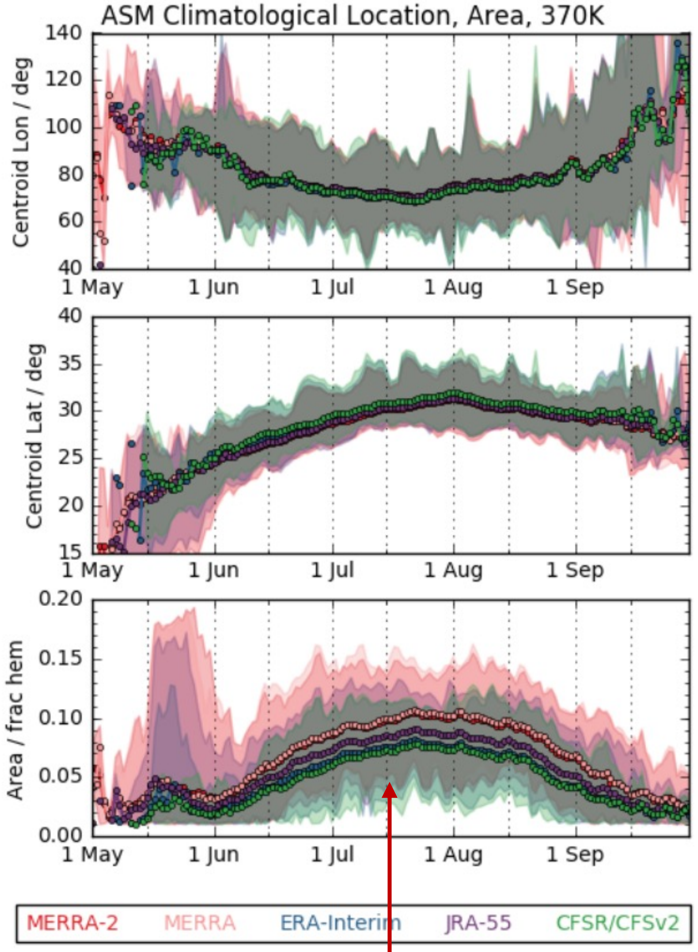
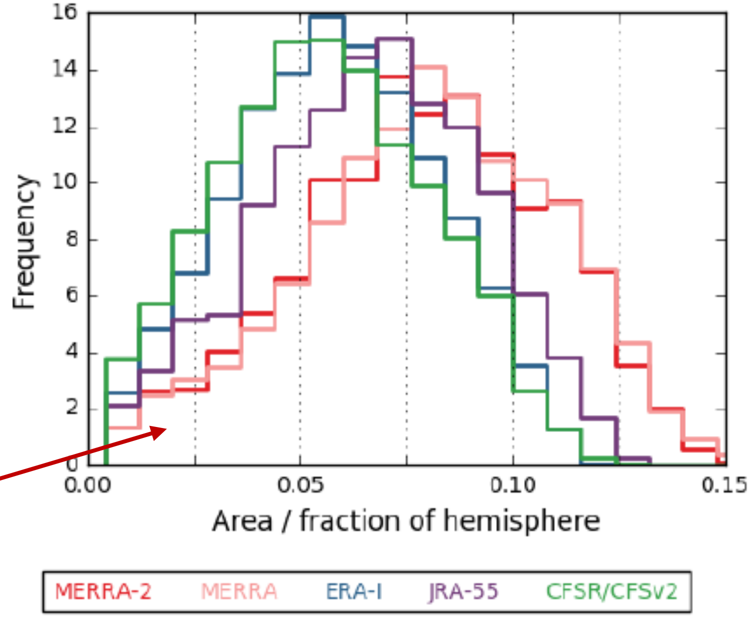
S-RIP: Key Findings and Recommendations

...but even recent reanalyses can differ substantially





[Manney et al., JClim 2021; S-RIP Chapter 8]



MERRA-2 area much larger, especially at 350K — why? [answer on slide 19]

S-RIP: Key Findings and Recommendations

NCEP R1 and R2 are unsuitable for many diagnostics and should usually be avoided

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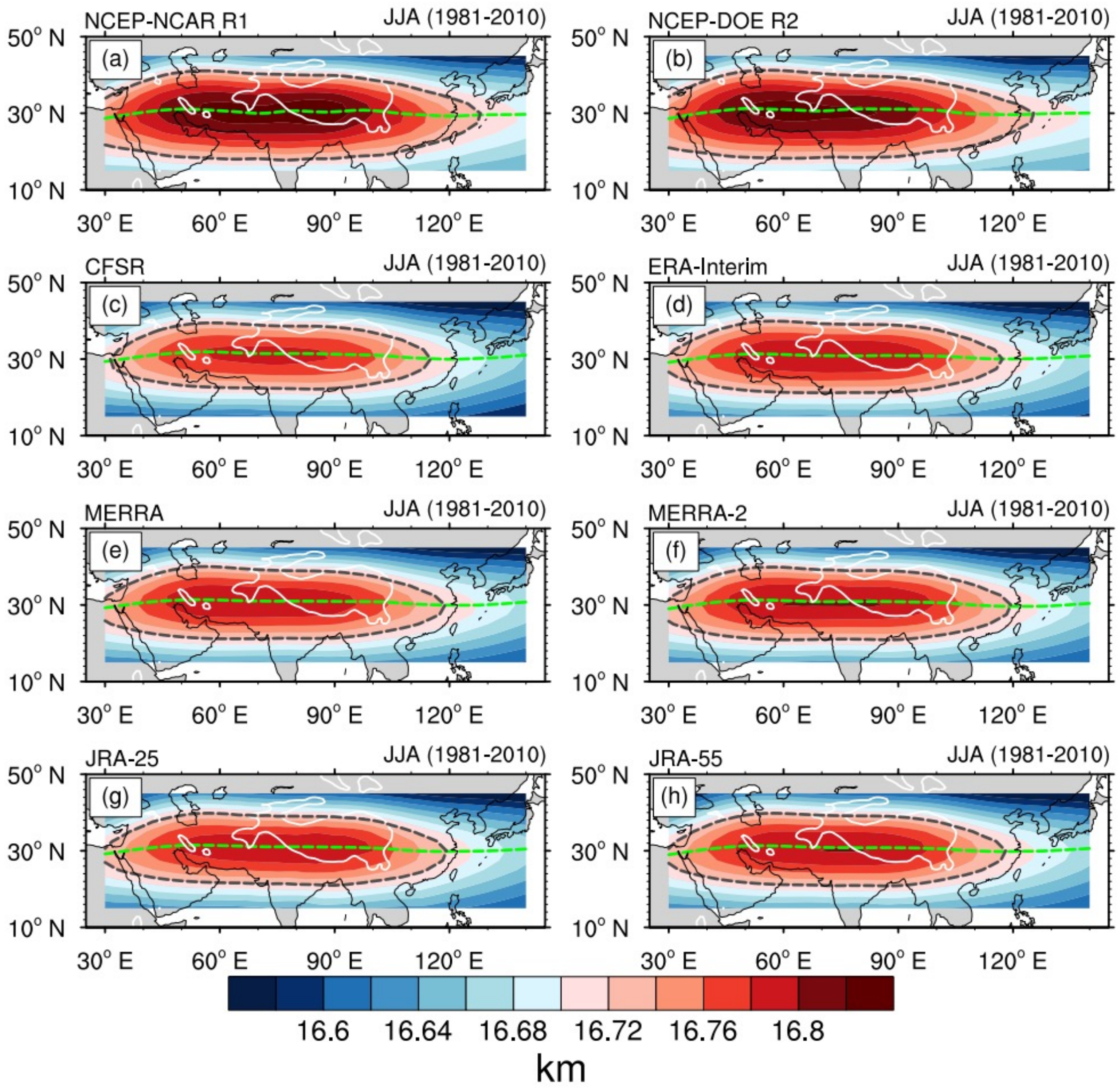
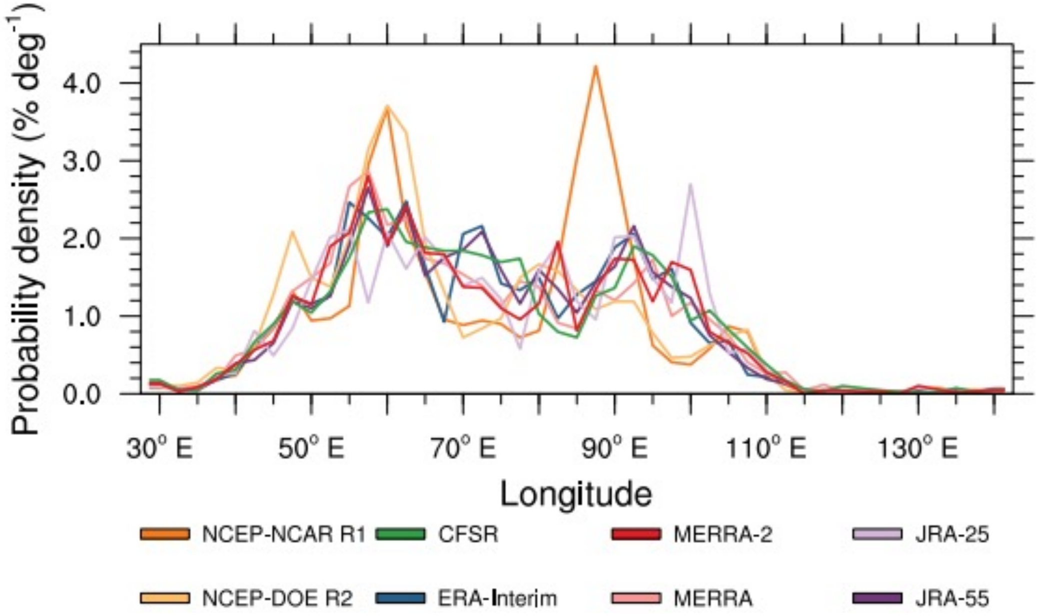


"For analyses involving the SASM anticyclone it is recommended to use more recent reanalyses. In particular, researchers are encouraged to **avoid NCEP-NCAR R1 and NCEP-DOE R2 data sets** and the geopotential height field of the MERRA-2-ANA pressure-level data."



[Nützel et al., ACP 2016; S-RIP Chapter 8]

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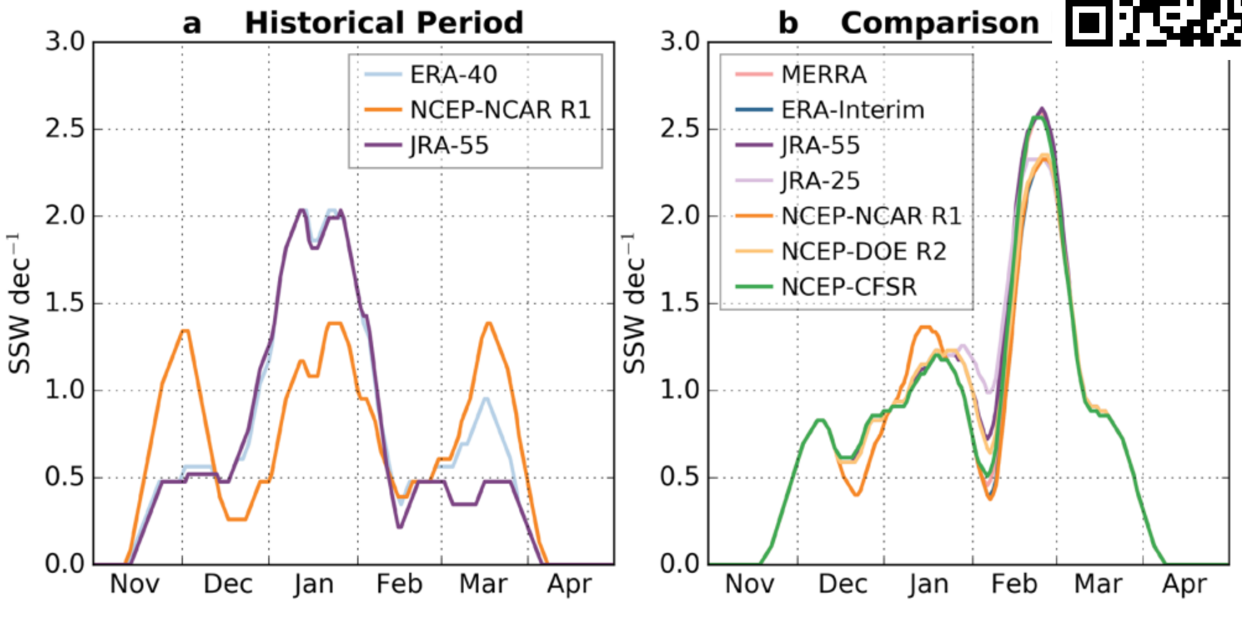
S-RIP: Key Findings and Recommendations

Conventional-input and pre-satellite reanalyses should be carefully validated

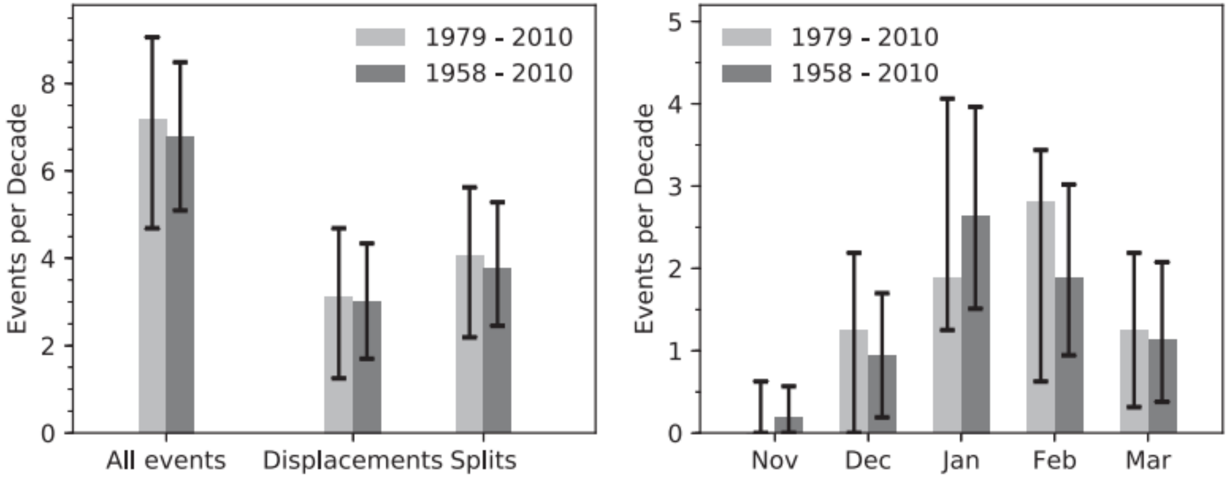
“Pre-satellite era reanalyses (1958 - 1978) appear to be of good quality in the **Northern Hemisphere**, and **can be used to reduce sampling uncertainty in measures of stratosphere-troposphere coupling** by approximately 20% … a more significant reduction in uncertainty than achieved by shifting from an earlier generation reanalysis to a more recent one.”

“Pre-satellite era reanalyses of the **Southern Hemisphere** are generally of **poor quality and can only be used to reduce sampling uncertainty with great caution.**”

Name	post-satellite era, 1979 - present NH	SH	pe-satellite era, 1958 - 979 NH	SH
ERA-40	consistent	consistent	consistent *	inconsistent
ERA-Interim †	recommended	recommended	n.a.	n.a.
ERA-20C	use w/ caution	use w/ caution	use w/ caution	use w/ caution
JRA-25	consistent	consistent	n.a.	n.a.
JRA-55	recommended	recommended	recommended *	inconsistent
JRA-55C	consistent *	use w/ caution	n.a.	n.a.
JRA-55AMIP	inconsistent	inconsistent	inconsistent	inconsistent
MERRA	consistent	consistent	n.a.	n.a.
MERRA-2	recommended	recommended	n.a.	n.a.
NCEP-R1	consistent *	consistent *	consistent *	inconsistent
NCEP-R2	consistent *	consistent *	n.a.	n.a.
CFSR	recommended	recommended	n.a.	n.a.
CFSv2	recommended	recommended	n.a.	n.a.
20CR v2	inconsistent	inconsistent	inconsistent	inconsistent
20CR v2c	inconsistent	inconsistent	inconsistent	inconsistent



(a) (b)



[Ayarzagüena et al., ACP 2019; Hitchcock, ACP 2017; S-RIP Chapter 6]

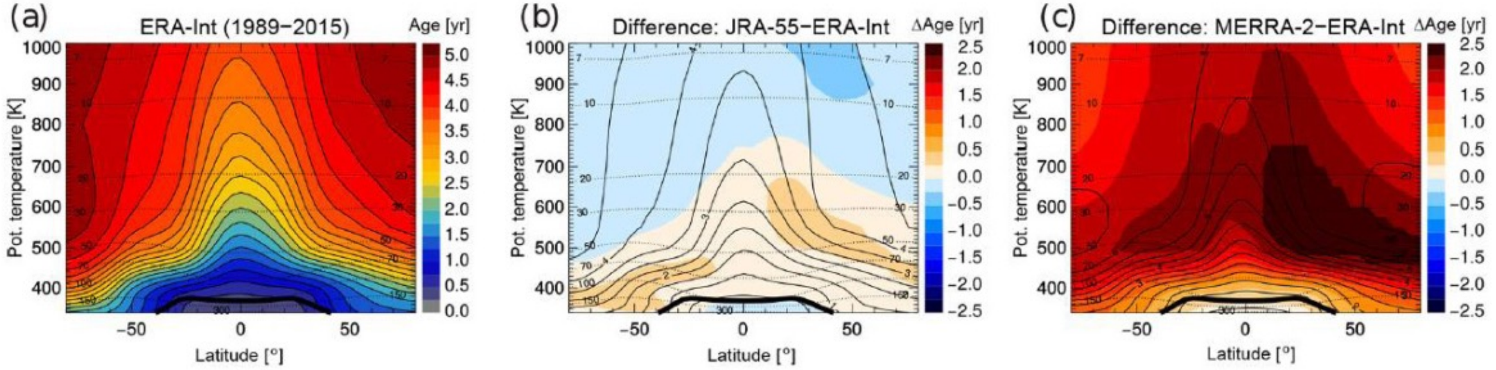
S-RIP: Key Findings and Recommendations

Use multiple reanalyses whenever possible

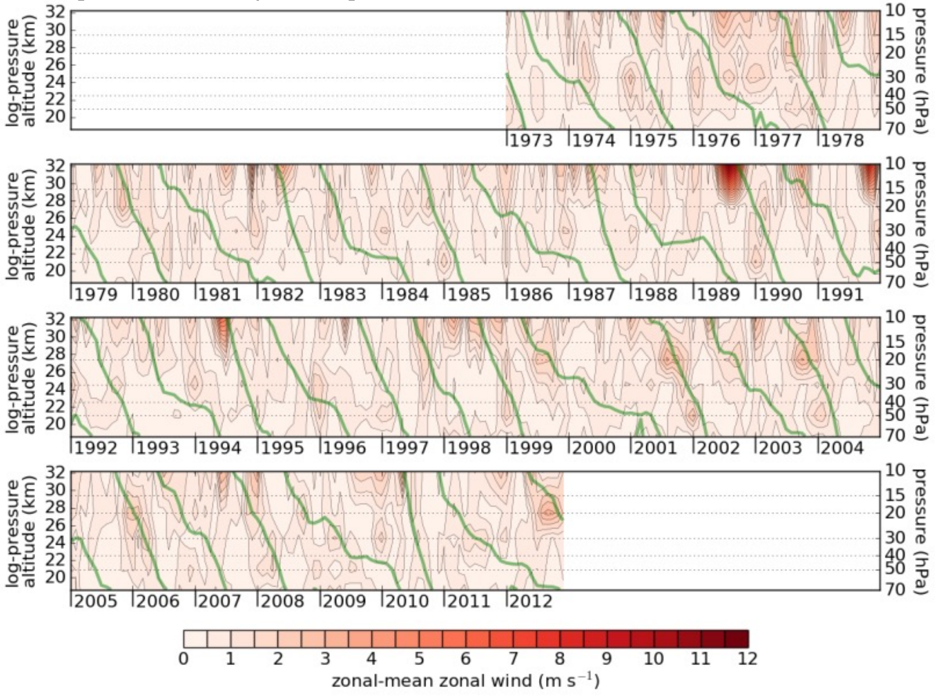
To evaluate consistency or uncertainty:

“Whenever possible we **recommend users not to restrict themselves to only one product when it comes to BDC studies**. In particular, for the period after 2000, a comparison between MERRA-2, JRA-55, and ERA-Interim … can help to distinguish robust from non-robust diagnostics”

[Ploeger et al., ACP 2019; S-RIP Chapter 5]



[S-RIP Chapter 9]



To test hypotheses about the role of data assimilation:

“We attribute the good representation [of the QBO] to the primary importance of tropical radiosonde wind observations in constraining the tropical stratospheric winds up to altitudes of 10hPa. This is **evidenced by the excellent agreement between JRA-55 and JRA-55C reanalyses**, as well as by the fact that extended reanalyses such as ERA-40 and JRA-55 agree well with each other and the FUB winds in the pre-satellite era.”

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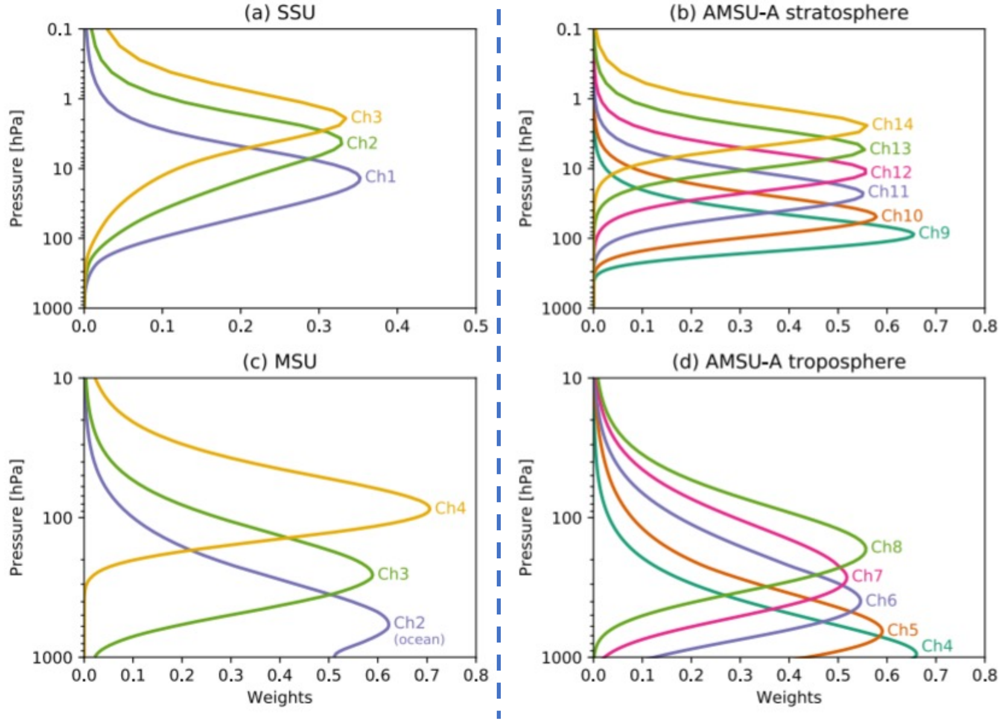
S-RIP: Key Findings and Recommendations

Caution: all reanalyses show discontinuities – be careful with long-term trends and variability!

(1978-2006) | (1998-present)



Vertical weighting functions of **temperature-sensitive** radiance measurements for SSU & MSU (1978-2006) and AMSU-A (1998-present). [S-RIP Chapter 2, Figure 2.16]

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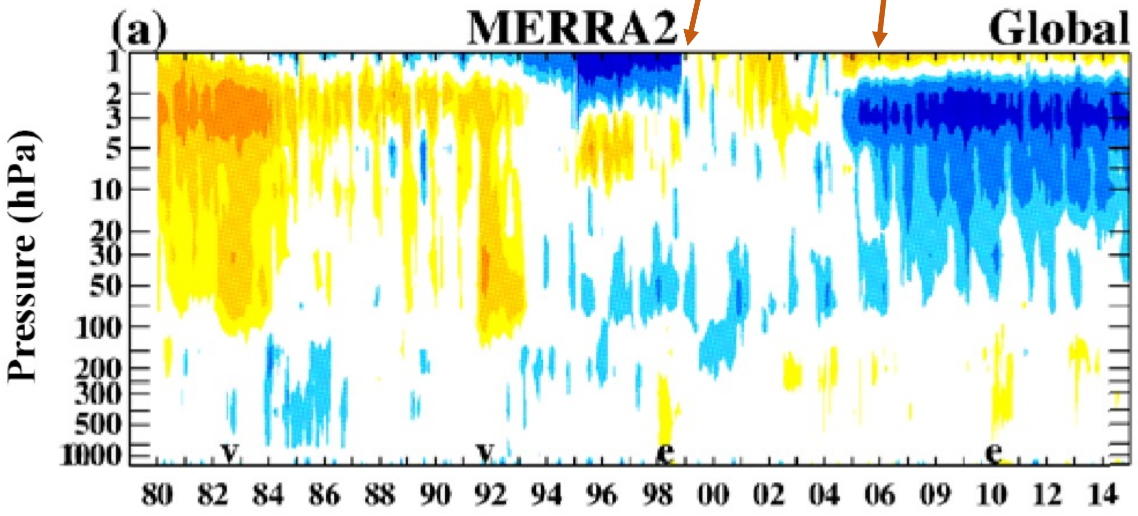
MLS: above 5 hPa level (2004~)
GNSS RO: UTLS (<30 km) (2004~)

TOVS (SSU instruments) . . . . ATOVS (AMSU-A) (1998~)



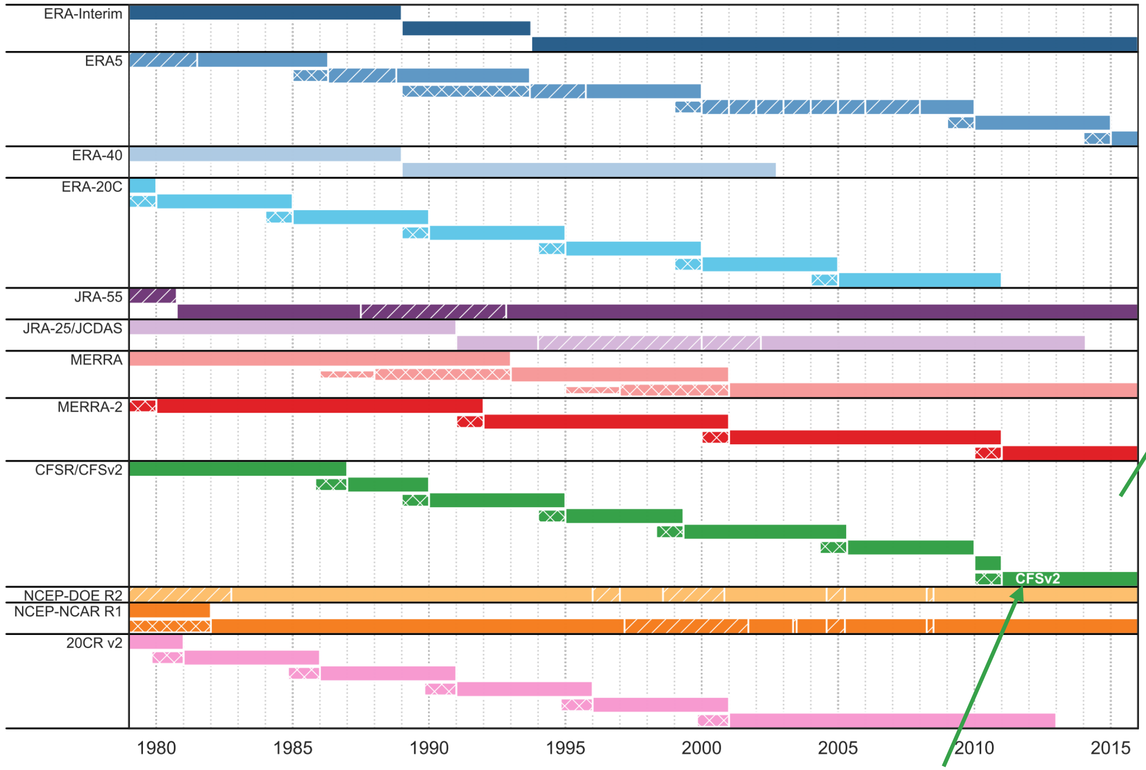
[Long et al., ACP 2017; S-RIP Chapter 3]

> "**The transition from the TOVS to ATOVS satellite periods**, starting around 1998-1999, is **problematic for all reanalyses**. In the stratosphere, the transition from three broad SSU IR channels to 5 narrower AMSU/ATMS microwave layers proves to be problematic for data assimilation."

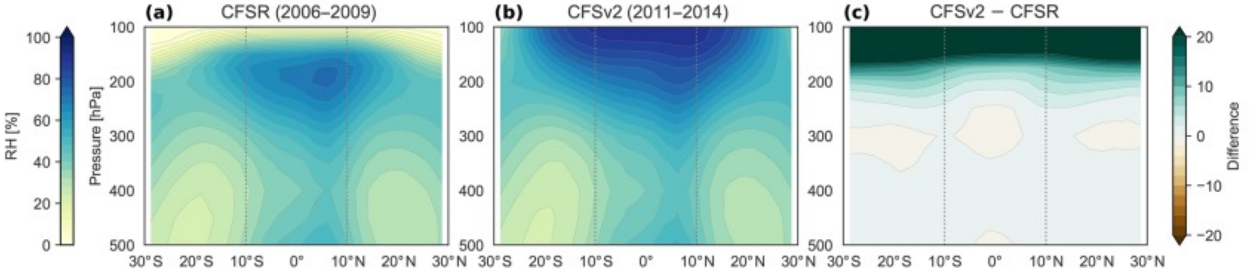
S-RIP: Key Findings and Recommendations

Discontinuities are especially pronounced in CFSR

[S-RIP Chapter 2, Figure 2.19]



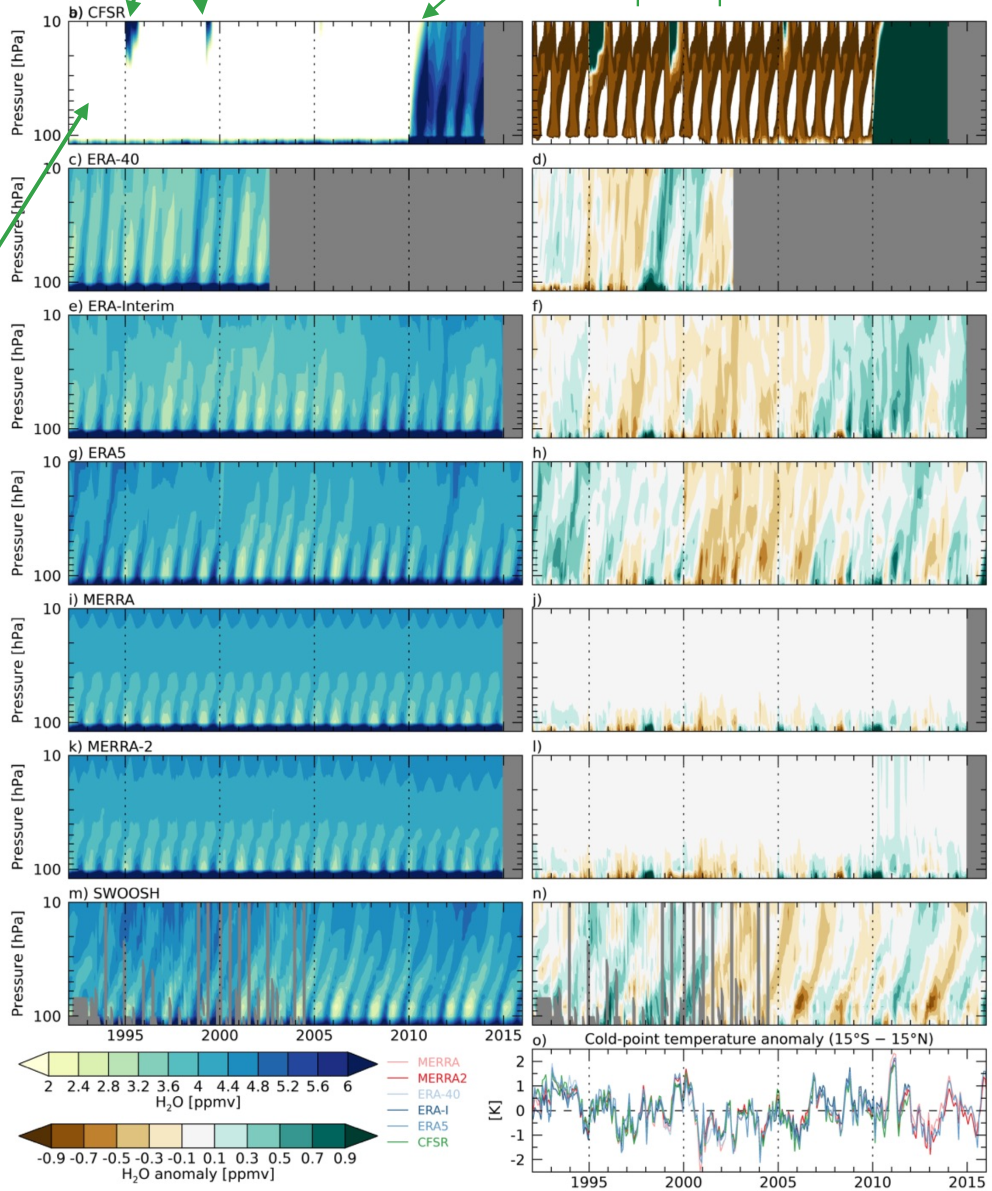
2011: new model!



[Wright et al., ACP 2020]

CFSR stream transitions following spin-up

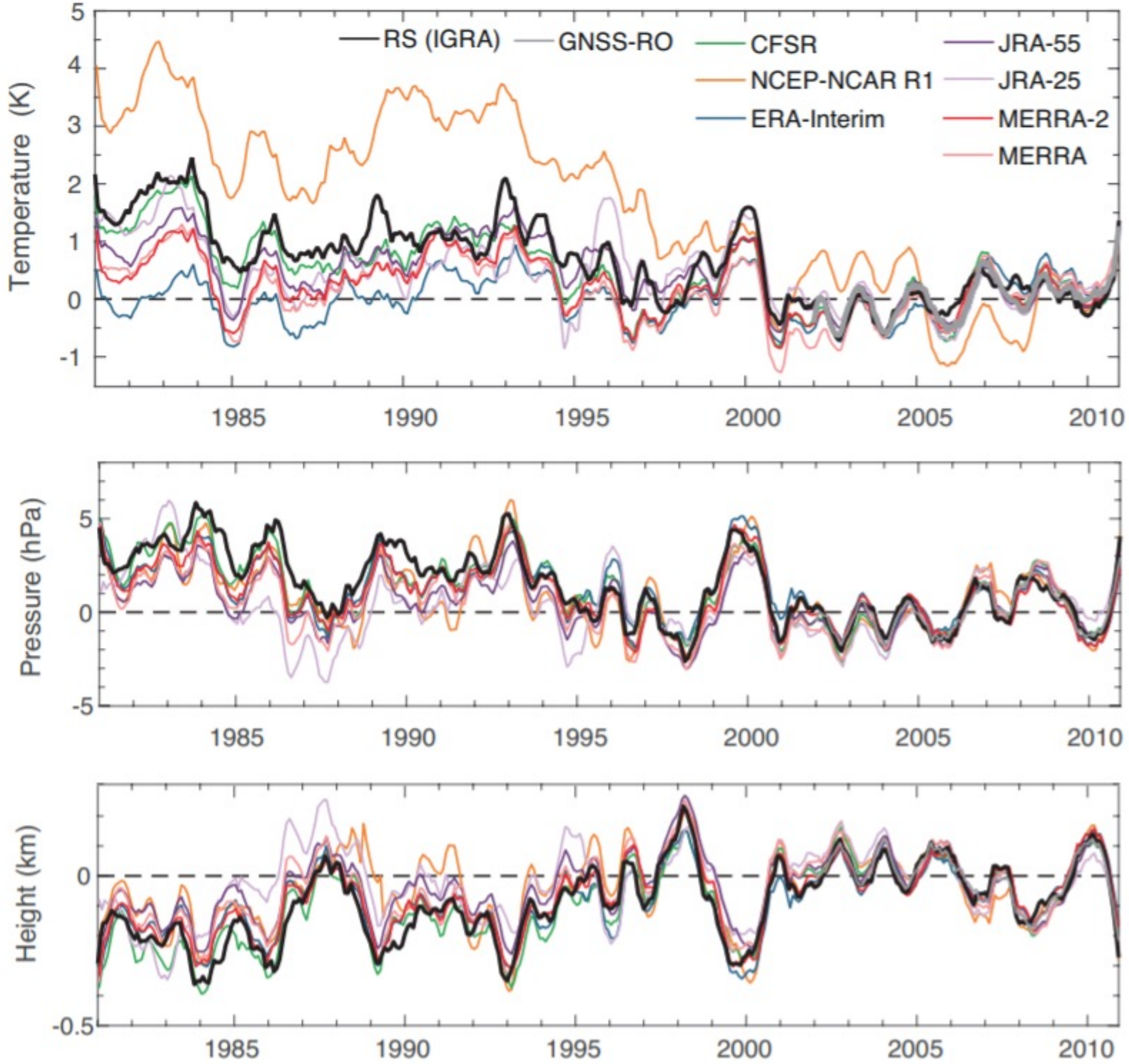
2010: no spin-up



[Davis et al., ACP 2017; S-RIP Chapter 4]

S-RIP: Key Findings and Recommendations

Be cautious when using reanalysis for long-term or trend analyses



- Cold point tropopause temperature trends from reanalyses range from zero to strong decreasing (cooling)
- Observational trends indicate a decrease, but are also uncertain, with no significant trend in recent years
- Reanalyses and observations consistently show increases in tropopause height over the 1980s and 1990s, consistent with cooling
- Check for (1) consistency across multiple reanalyses, (2) consistency with (ideally independent) observations, (3) clear and convincing physical explanation

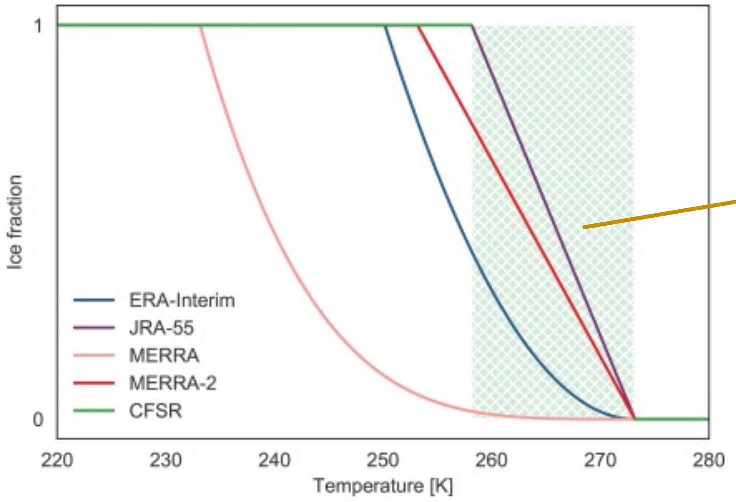
[S-RIP Chapter 8]

S-RIP: Key Findings and Recommendations

Reanalysis fields inherit biases from the underlying forecast model

> "model physical parameterizations can have systematic impacts not only on forecast variables but also on analyzed variables (e.g., temperature and humidity)…"

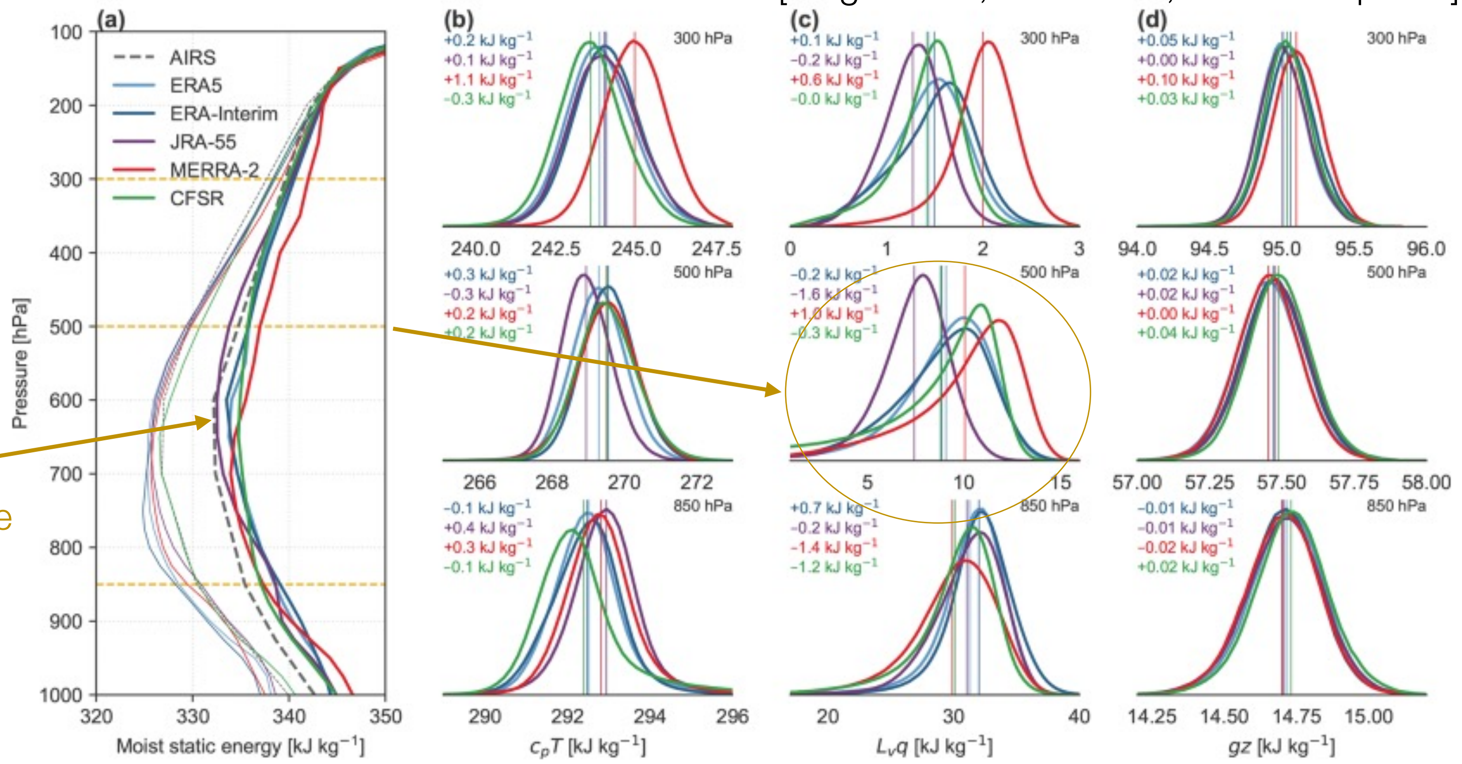
[S-RIP Chapter 2]



mixed phase partitioning

Note also MERRA-2 warm and wet biases in upper troposphere! (more on next slide)

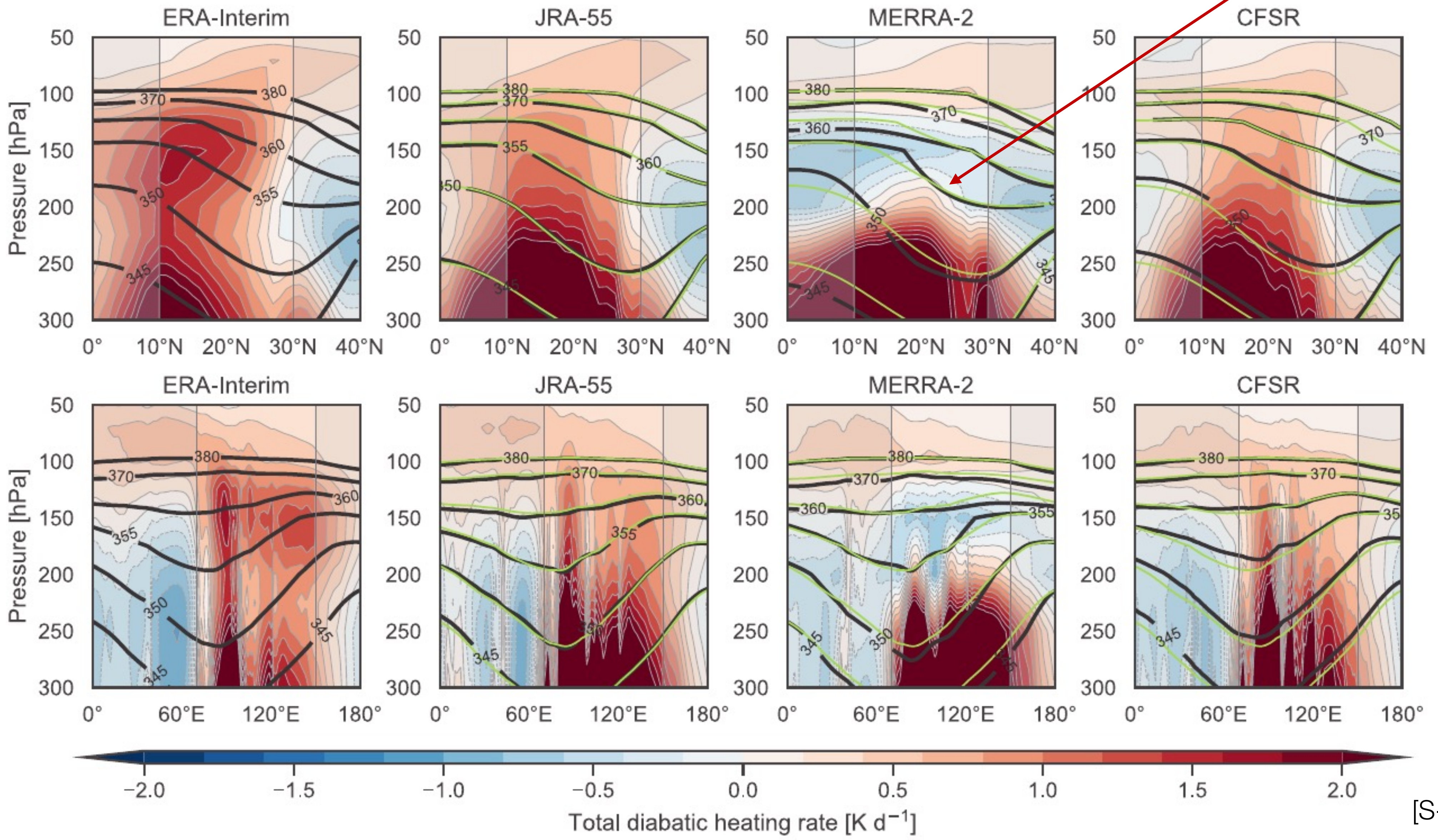
[Wright et al., ACP 2020; S-RIP Chapter 8]



Aside: MERRA-2 warm and moist bias in upper troposphere

Why do anticyclone diagnostics differ between *p*-levels and *θ*-levels?

Circulation on theta surfaces stretched & deformed by warm bias!

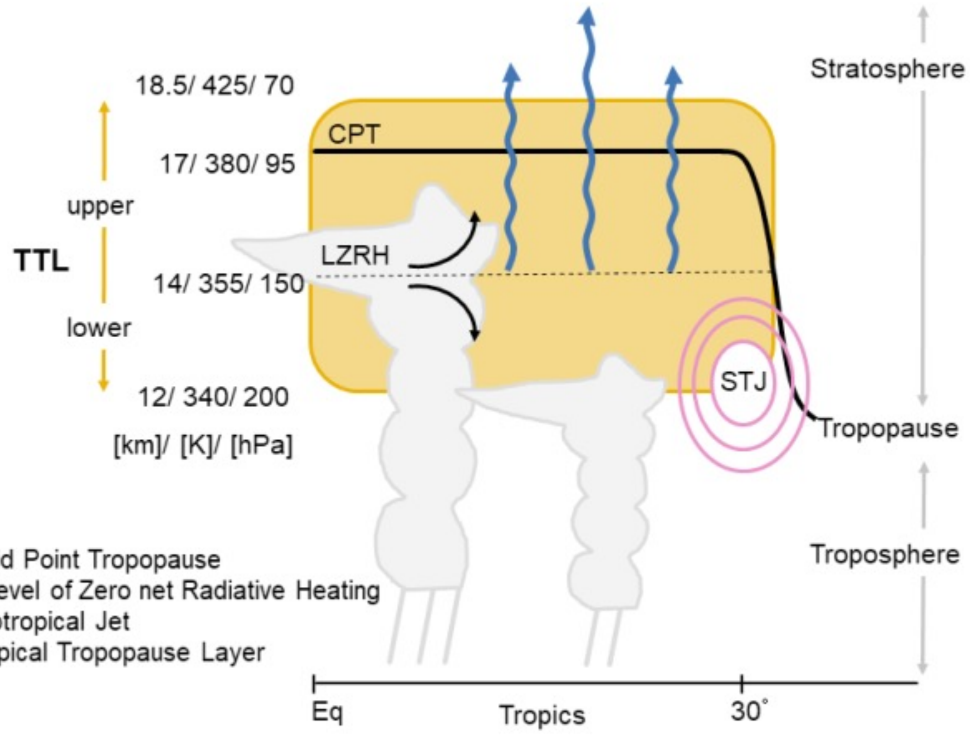


[S-RIP Chapter 8]

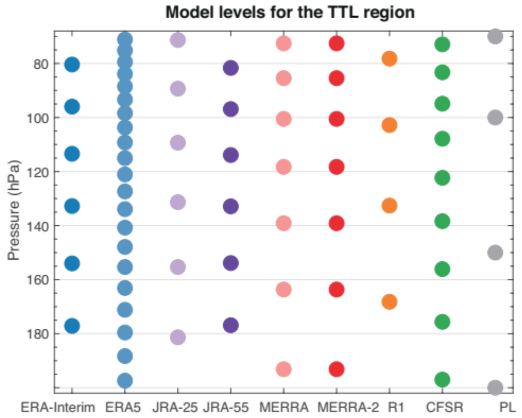
S-RIP: Key Findings and Recommendations

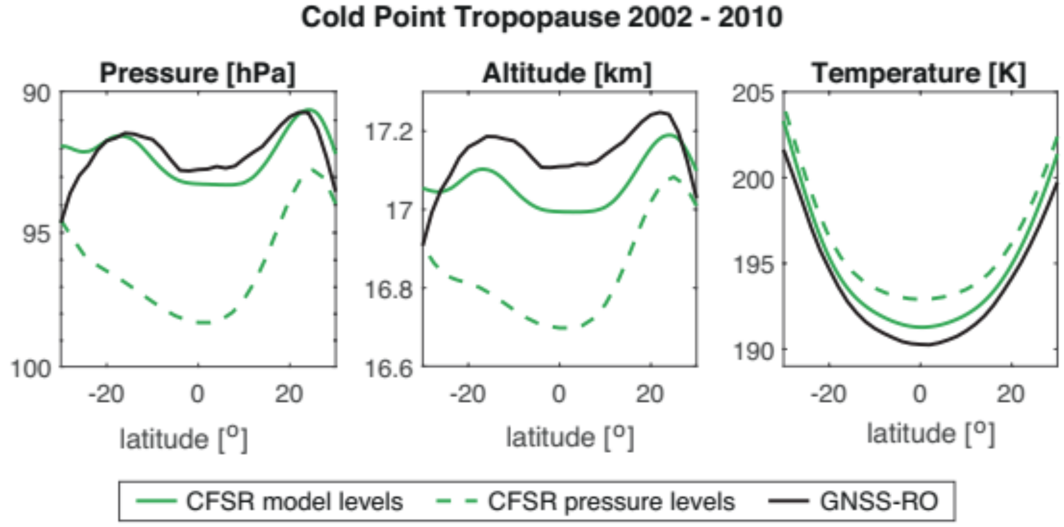
Recommendation: use products on model levels when sharp vertical gradients are involved

> "Various diagnostics such as the cold point and lapse rate tropopause and the analysis of equatorial waves are **demonstrably improved when model-level data are used.**"



CPT: Cold Point Tropopause
LZRH: Level of Zero net Radiative Heating
STJ: Subtropical Jet
TTL: Tropical Tropopause Layer





[Tegtmeier et al., ACP 2020; S-RIP Chapter 8]

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Note on model vertical grid and data assimilation

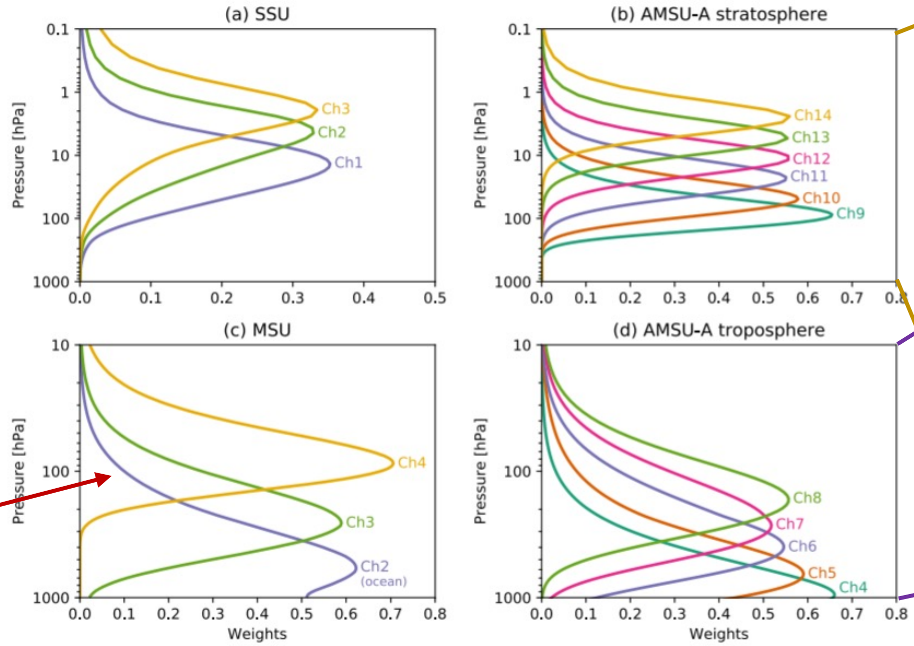
A potential downside of higher resolution?

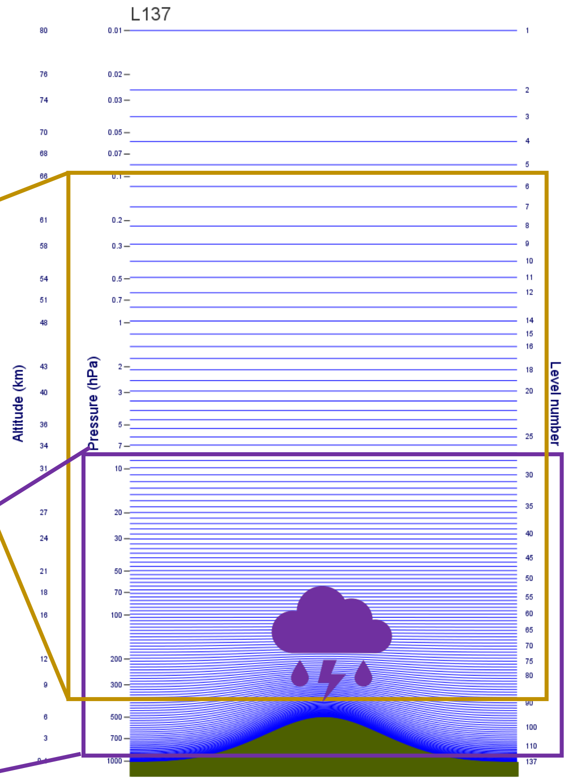
- Finer resolution
- More sophisticated physics
- More assimilated observations

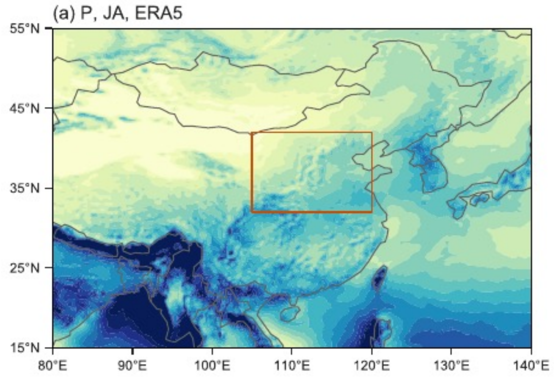
…not always "better"

CERA-20C and ERA5 use the same underlying model version, but at different resolutions — why is the bias in CERA-20C eliminated earlier (~1980 vs ~2013) despite weaker observational constraints? Hypothesis: mismatched vertical resolution of model and observations in ERA5 only fully solved with availability of hyperspectral sounders

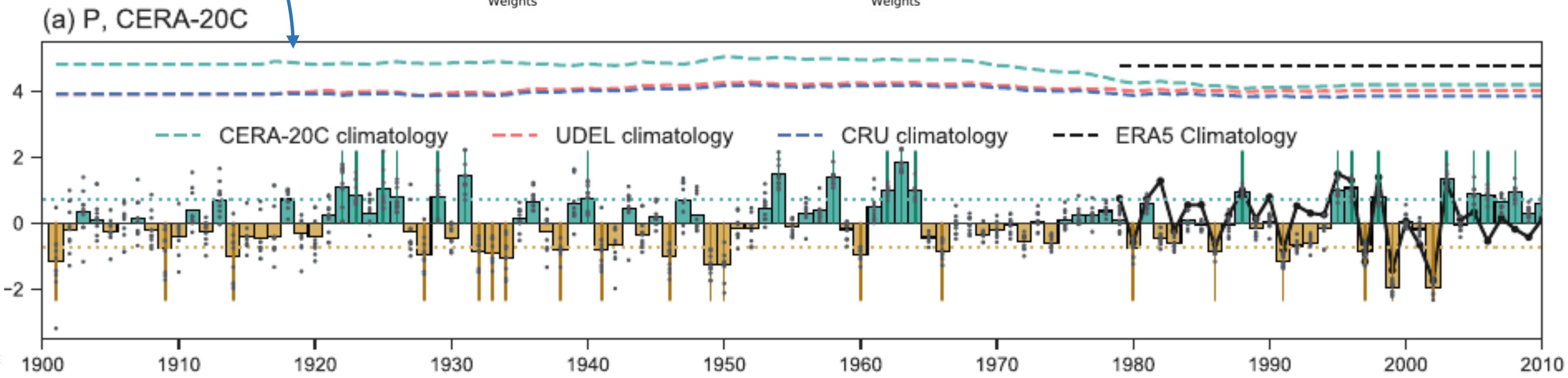
?





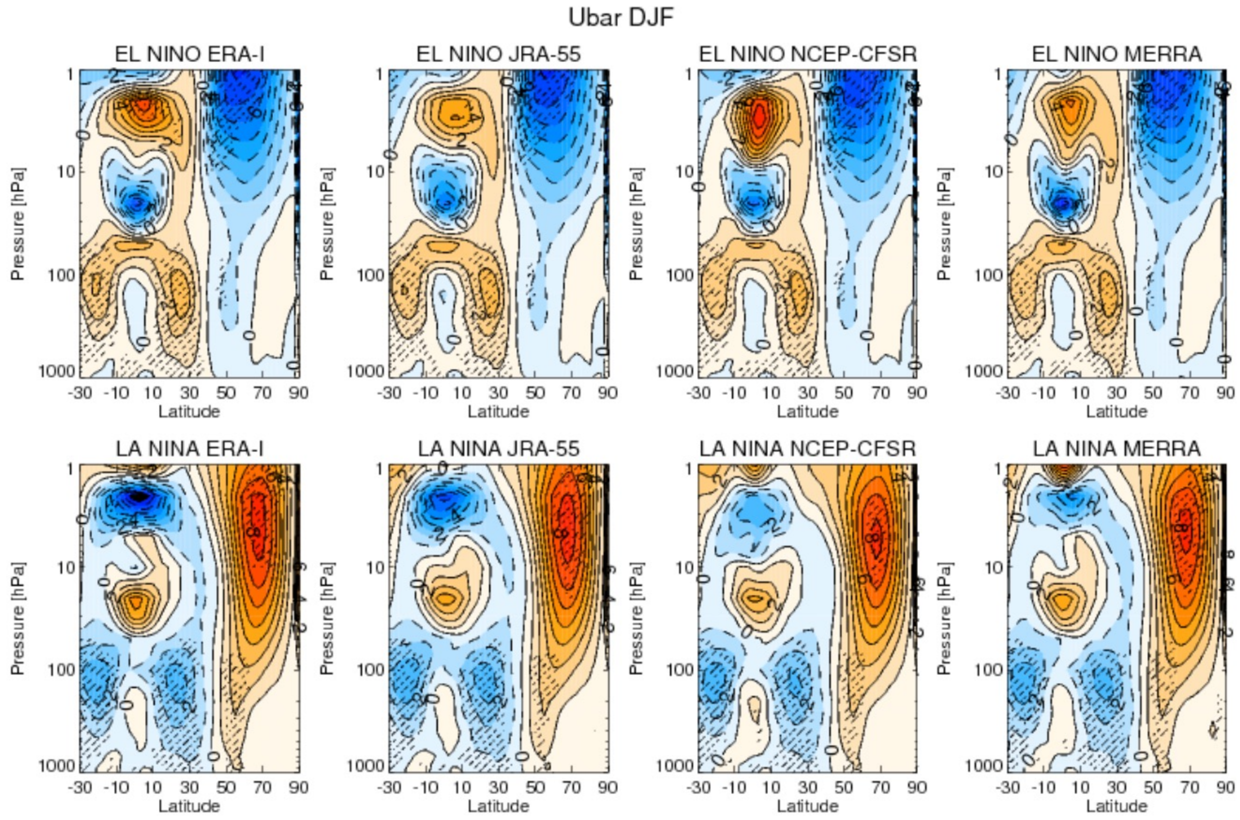


JJA climatology and analysis domain

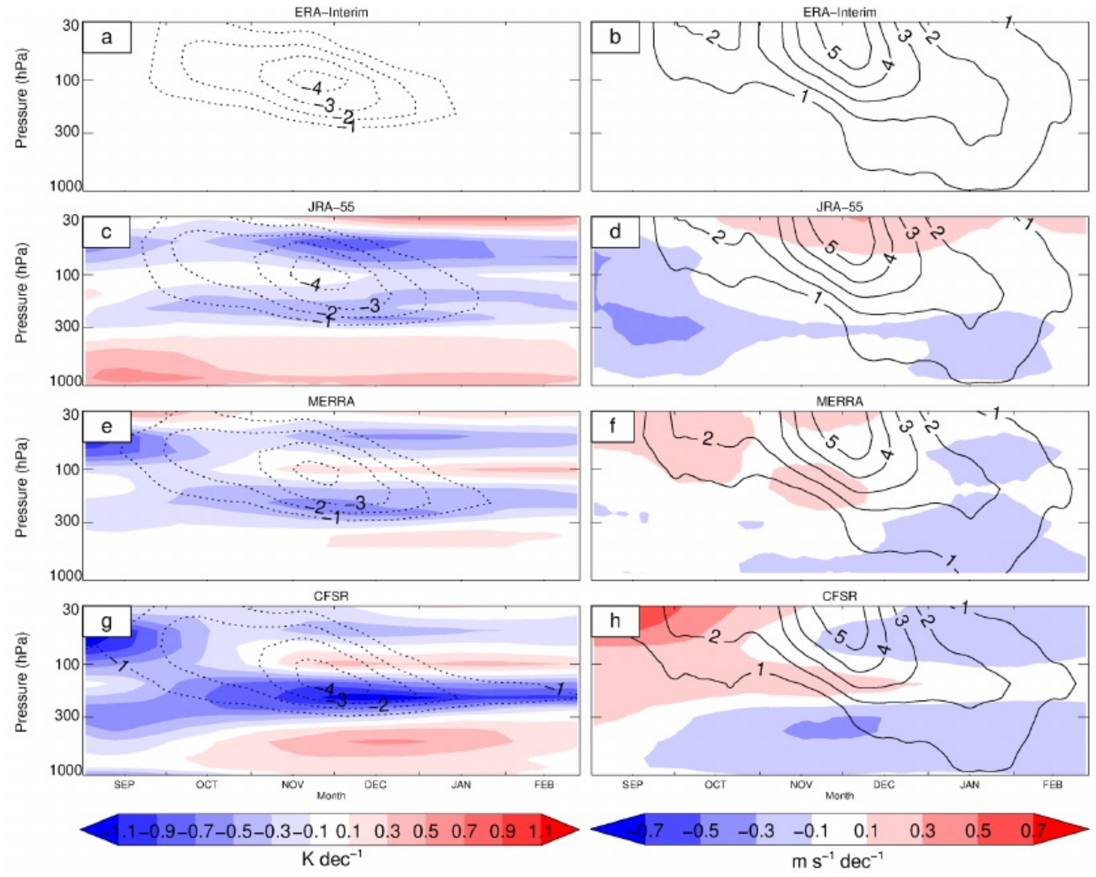


[Dai et al., 2020; Dai & Wright 2021]

Other Examples From the S-RIP Report: Dynamical Fields



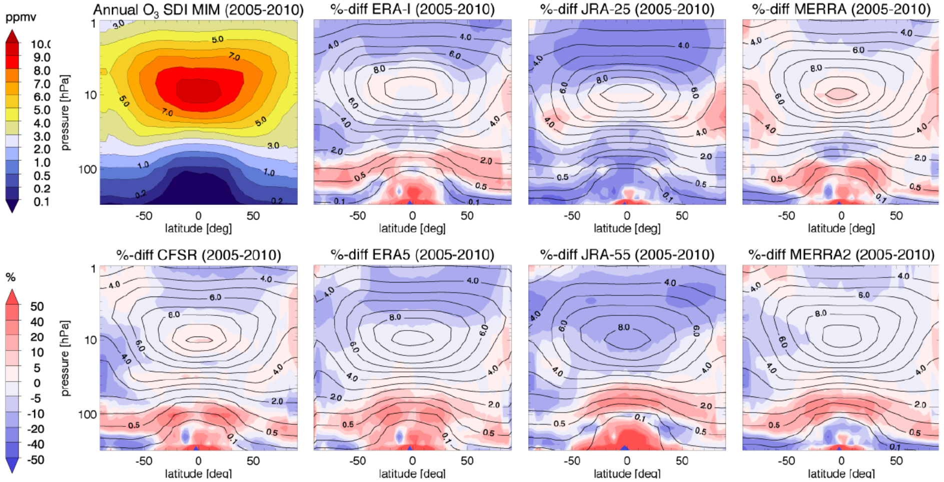
ENSO circulation response
[Chapter 6]
A good agreement across reanalyses is found for El Niño and La Niña polar stratospheric responses, despite some differences in the tropics



Temperature and wind responses to ozone depletion
[Chapter 6]
Large differences among reanalyses arise from poor representations of Antarctic ozone depletion, which depend strongly on parameterized heterogeneous chemistry.

S-RIP Final Report

Other Examples From the S-RIP Report: Ozone

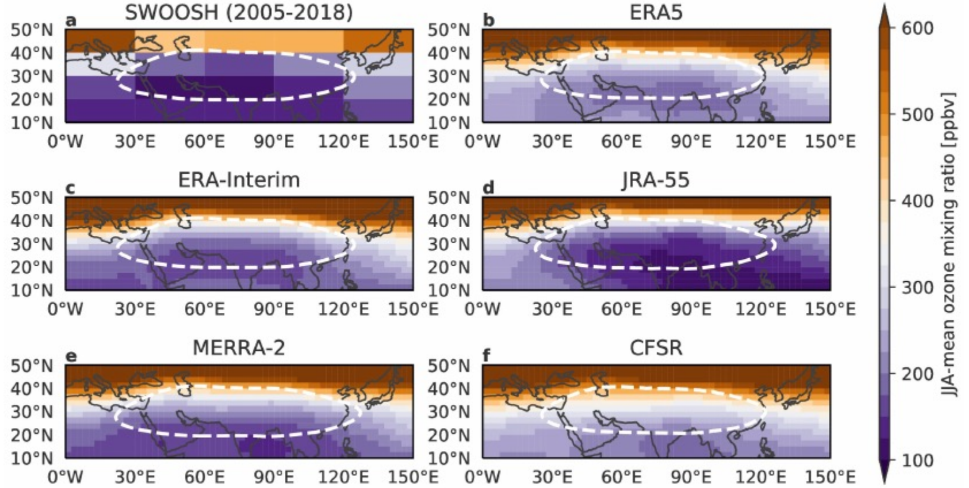


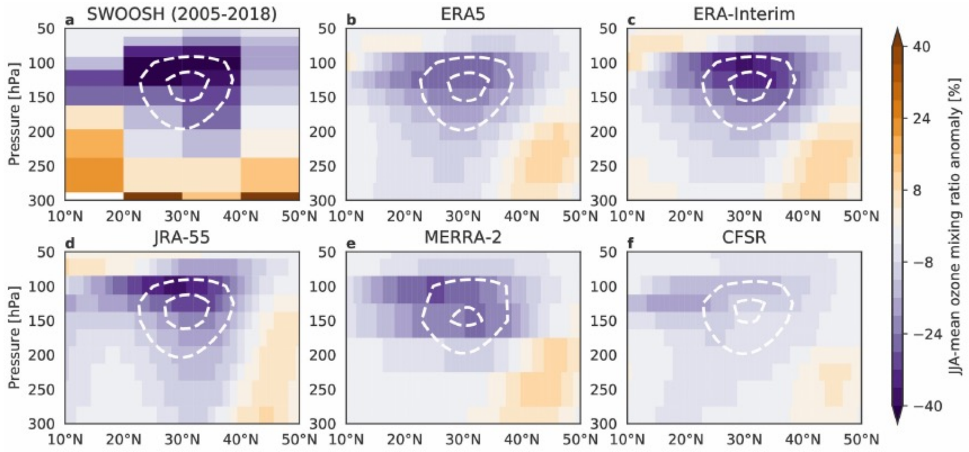
Ozone overview
[Chapter 4]

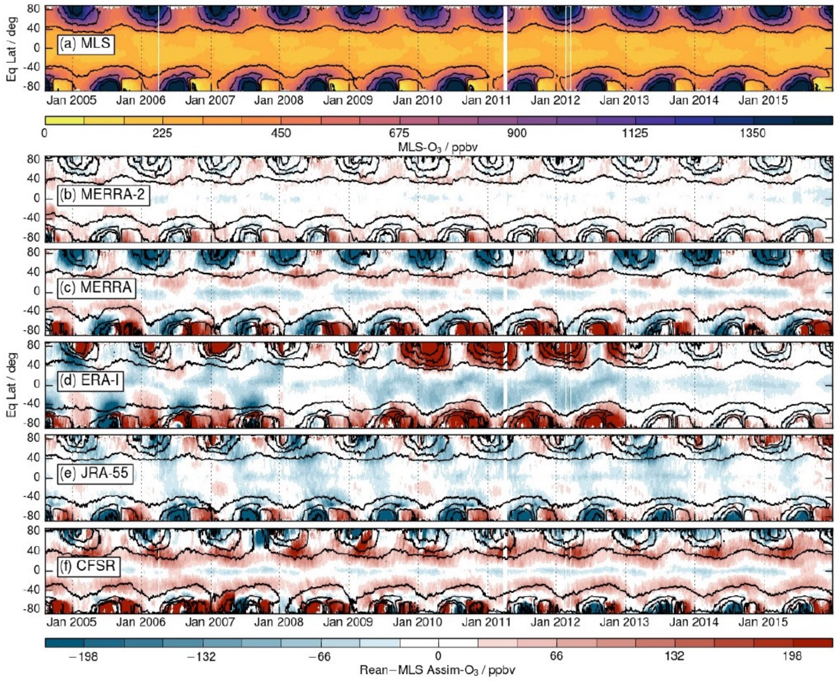
Comparison of annual zonal mean reanalysis ozone with the SPARC Data Initiative Multi-Instrument Mean shows that recent reanalyses (especially ERA5, MERRA-2, CFSR) capture well the broad aspects of observed ozone distributions.

Asian monsoon “ozone valley”
[Chapter 8]

None of the current reanalyses, even those assimilating MLS data, fully captures the ozone decrease in the ASM anticyclone





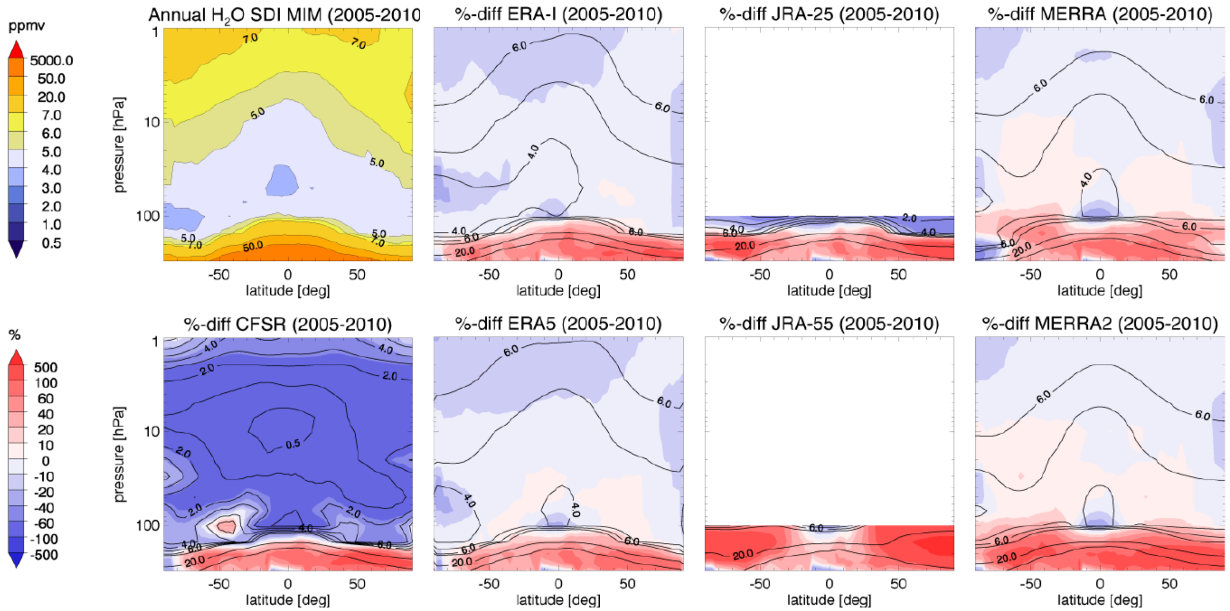


Ozone distribution and evolution in the lowermost stratosphere
[Chapter 7]

Large differences among reanalyses arise from reanalyses poorly representing Antarctic ozone depletion, which depends strongly on each model’s parameterized heterogeneous chemistry.

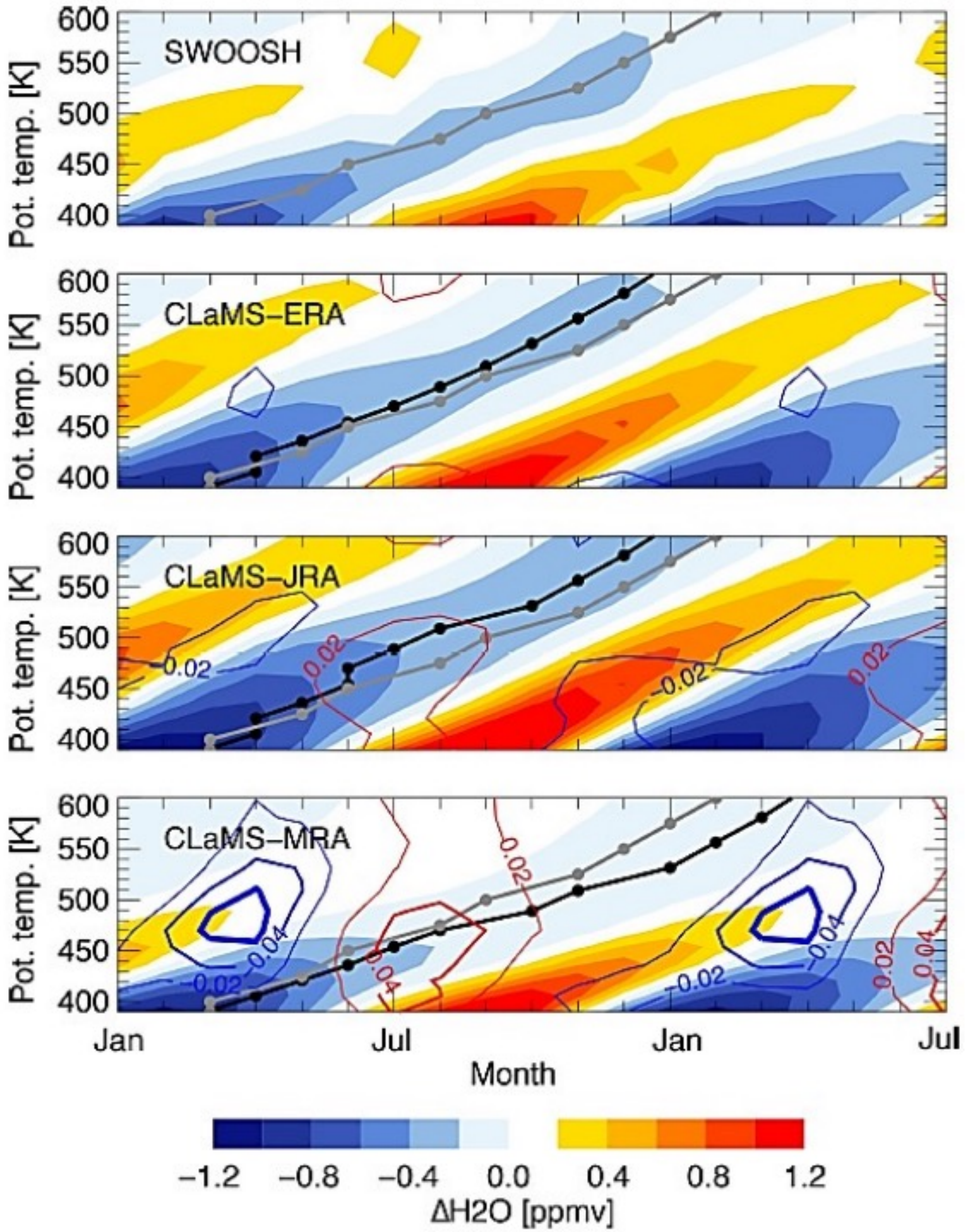
S-RIP Final Report

Other Examples From the S-RIP Report: Stratospheric Water Vapor



Water vapor overview
[Chapter 4]

Reanalysis products are generally unsuitable for studying stratospheric water vapor and its variations. Reanalyses only assimilate water vapor below the tropopause and often rely on satellite-based climatologies to represent the radiative impacts of SWV (e.g., JRA-55, MERRA, MERRA-2). Only ERA-Interim and ERA5 provide physically meaningful variations in SWV.



Tropical tape recorder simulated using reanalysis winds
[Chapter 5]

Reanalyses show significant differences in the intensity and upward propagation of the tape recorder signal.

S-RIP Final Report

Now in progress:
Phase 2 → A-RIP

- Continuing the activity through at least 2028
- Specific plans depend on participants, but will include:
  - Evaluation of new and forthcoming reanalyses
  - Evaluation of reanalyses of atmospheric composition, both those focusing on upper tropospheric and stratospheric processes and those focusing on air quality applications
  - Evaluation of tropospheric circulation (e.g., blocking, Rossby-wave breaking, jets and storm tracks) in relation to both stratospheric influences and extreme weather events
  - More comprehensive evaluation of monsoon circulations and dynamics, including atmospheric composition
  - More extensive comparisons of the upper stratosphere and mesosphere using newer reanalyses with higher tops
  - New joint special issue in ACP and WCD – open for submissions!

APARC
Atmospheric Processes And their Role in Climate

ccmi
chemistry-climate model initiative

TOAR
tropospheric ozone assessment report

ACAM
ATMOSPHERIC COMPOSITION & THE ASIAN MONSOON

New inter-journal special issue

Now open in ACP and WCD

A·RIP APARC Reanalysis Intercomparison Project

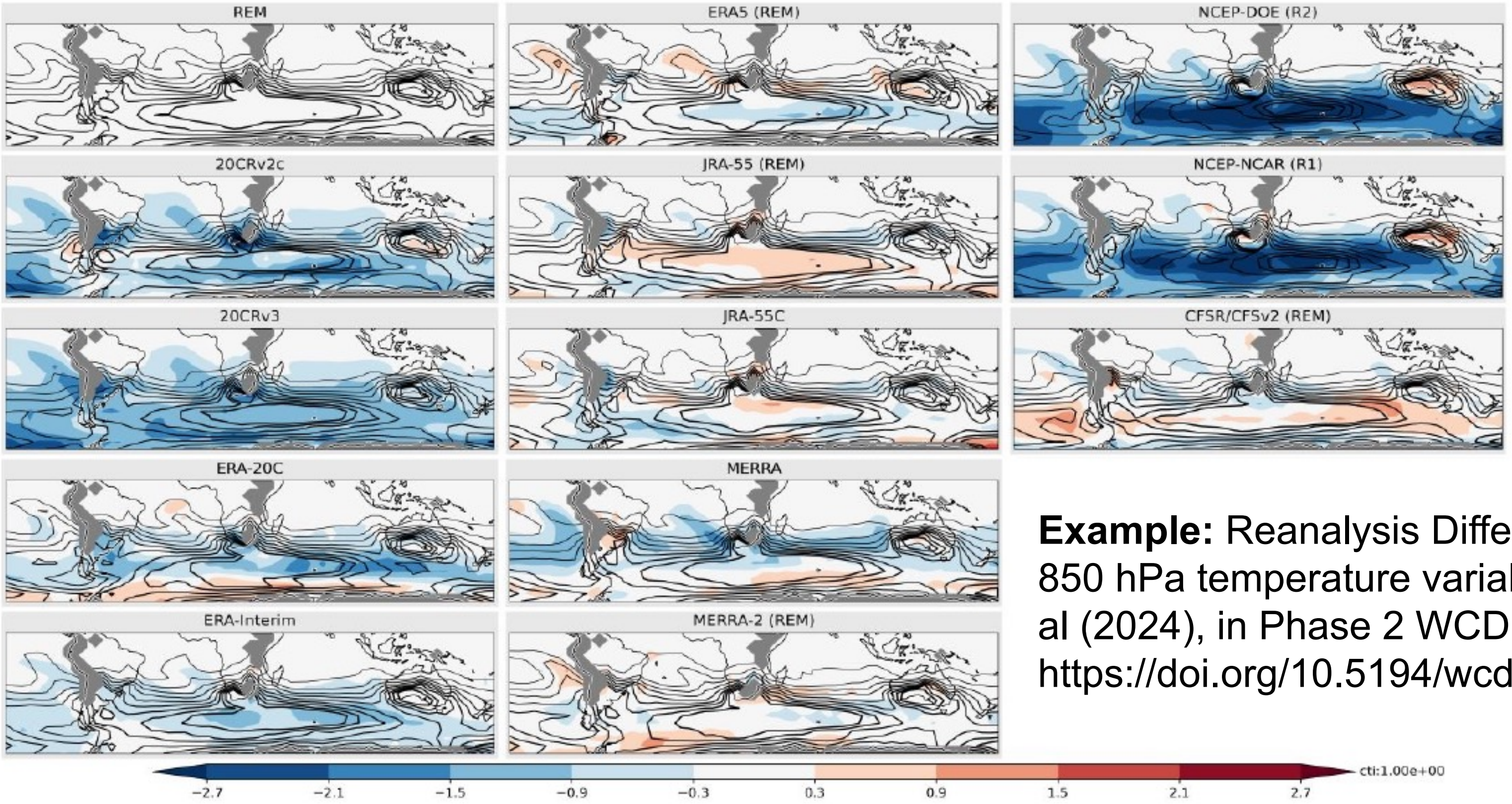
New inter-journal special issue on "The SPARC Reanalysis Intercomparison Project (S-RIP) Phase 2" in Atmospheric Chemistry and Physics (ACP) & Weather and Climate Dynamics (WCD):
Opened: 1 January 2023
Closes: 31 December 2028

[https://acp.copernicus.org/articles/special_issue1242.html]

ACP

[https://wcd.copernicus.org/articles/special_issue10_1242.html]

WCD



Example: Reanalysis Differences from REM of 850 hPa temperature variability. From Martineau et al (2024), in Phase 2 WCD Special Issue: https://doi.org/10.5194/wcd-5-1-2024

Updated zonal-mean dynamical dataset

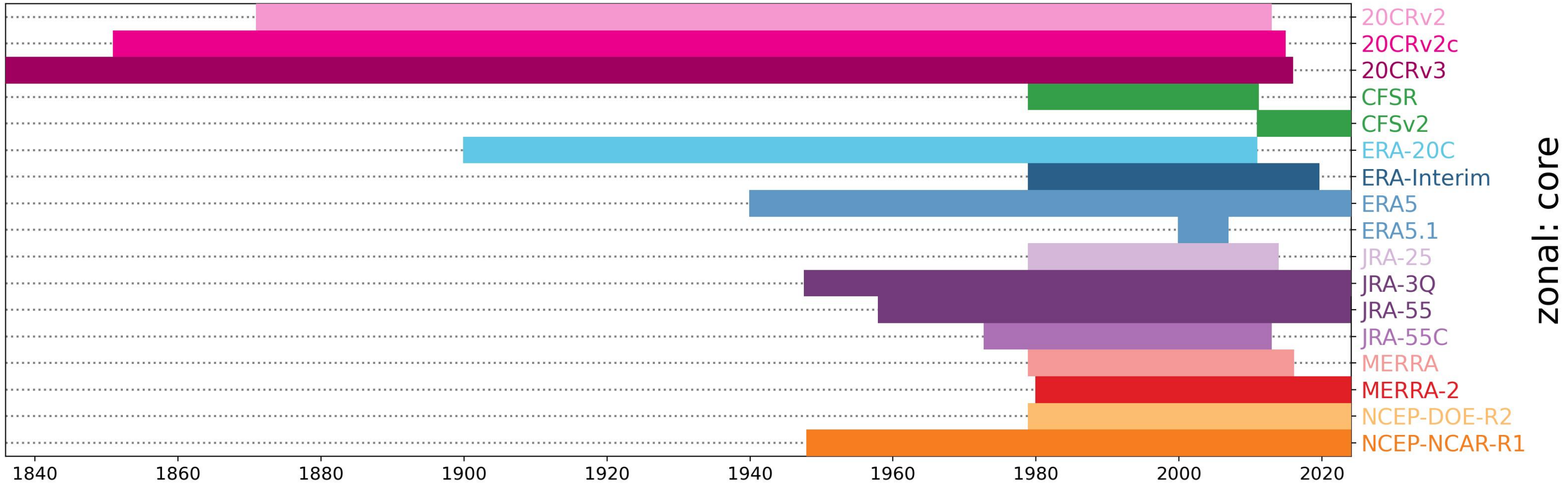
Now available from Patrick Martineau

https://www.jamstec.go.jp/ridinfo/

APARC Reanalysis Intercomparison Project

- An extended version of the dynamical part of the zonal mean data set by Martineau et al. (ESSD, 2018) plus several new diagnostics, ERA5, and JRA-3Q.
- Diagnostics for ongoing reanalyses are updated regularly, and new reanalyses will be added as they become available
- Periods of availability for each reanalysis for most diagnostics here

[RID Landing Page]



Now available: JRA-3Q

Japanese Reanalysis for 3 Quarters of a Century

APARC Reanalysis Intercomparison Project

Reanalysis system	Period	Model	Horizontal grid	Vertical grid	Top level
JRA-25/JCDAS	1979 – 2014.1	JMA GSM (2004)	1.125°(T106)	40	0.4 hPa
JRA-55	1958 – present	JMA GSM (2009)	~55 km (TL319)	60	0.1 hPa
JRA-3Q	1947.9 – present	JMA GSM (2018)	~40 km (TL479)	100	0.01 hPa

- Uses further reprocessed/recalibrated (homogenized) observational data
- Boundary condition over ocean (replaces COBE-SST throughout for JRA-55):
  - Early part: COBE-SST2 (1 degree)
  - From around 1985 onward: MGDSST (0.25 degree) (NEW)
- Ozone data: Created with improved CCM (MRI-CCM2, TL159L64)
- The JRA-3Q project started in 2014 and has been produced in three streams
- Some initial evaluations have been presented at EGU and other meetings — for example, the Brewer-Dobson circulation is weaker than ERA5 in the NH and comparable in the SH

Targets: new sources of reanalysis products

CRA-40, CAFE60, IMDAA, …

A·RIP APARC Reanalysis Intercomparison Project

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

- Several new groups working to produce reanalyses with locally distinct characteristics
- Often complementary to or interdependent with prior reanalyses
- Unique focus areas and sources of observational data suggest new areas for analysis and intercomparison
- Intend to produce systematic documentation and evaluation
- May include additional regional reanalyses (Arctic, EU, North America) depending on areas of analysis

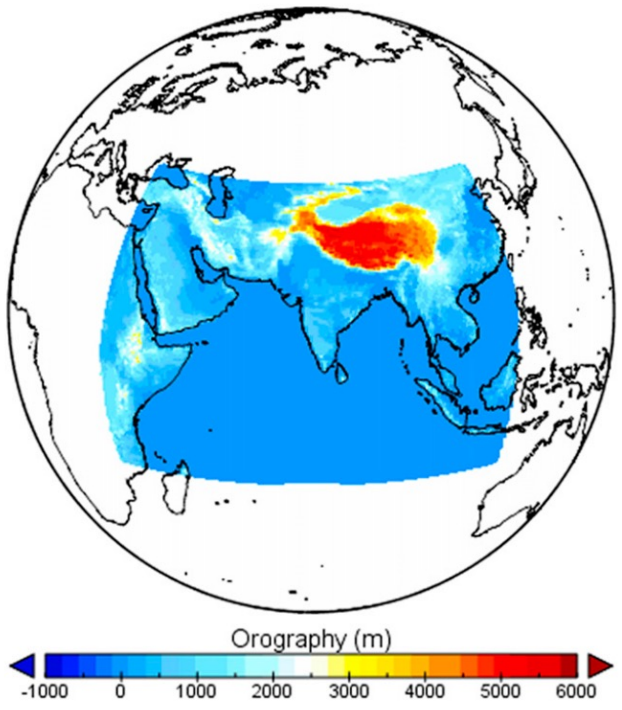


FIG. 1. IMDAA domain with model topography.

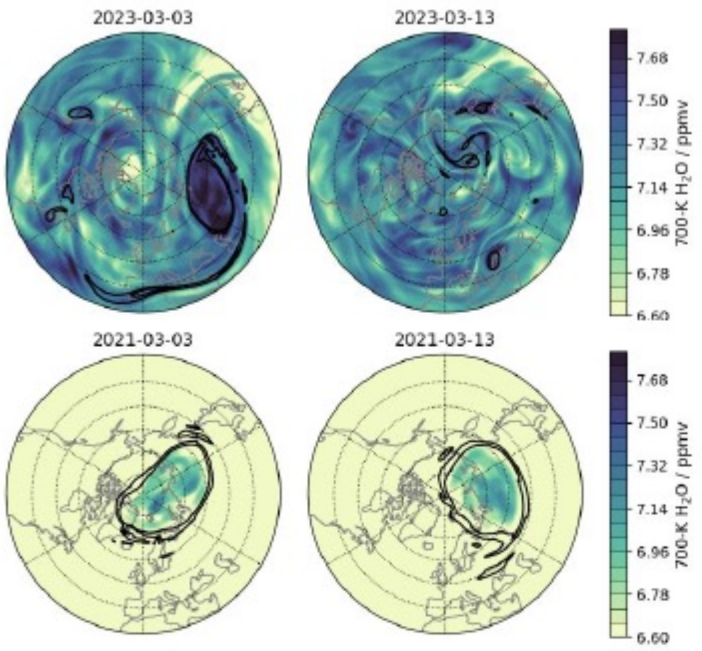
Targets: reanalyses of atmospheric composition

CAMS, BRAM2/3/(4), M2-SCREAM, TCR2/(3), R21C-Chem…

A·RIP
APARC Reanalysis Intercomparison Project

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

- Detailed 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, …)
- Chemistry-climate models of varying complexity
- Larger differences in assimilation methods and constraints
- Meteorological reanalyses provide O_3 but with simpler models
- Also examining aerosol analyses in MERRA-2, CAMS, etc.



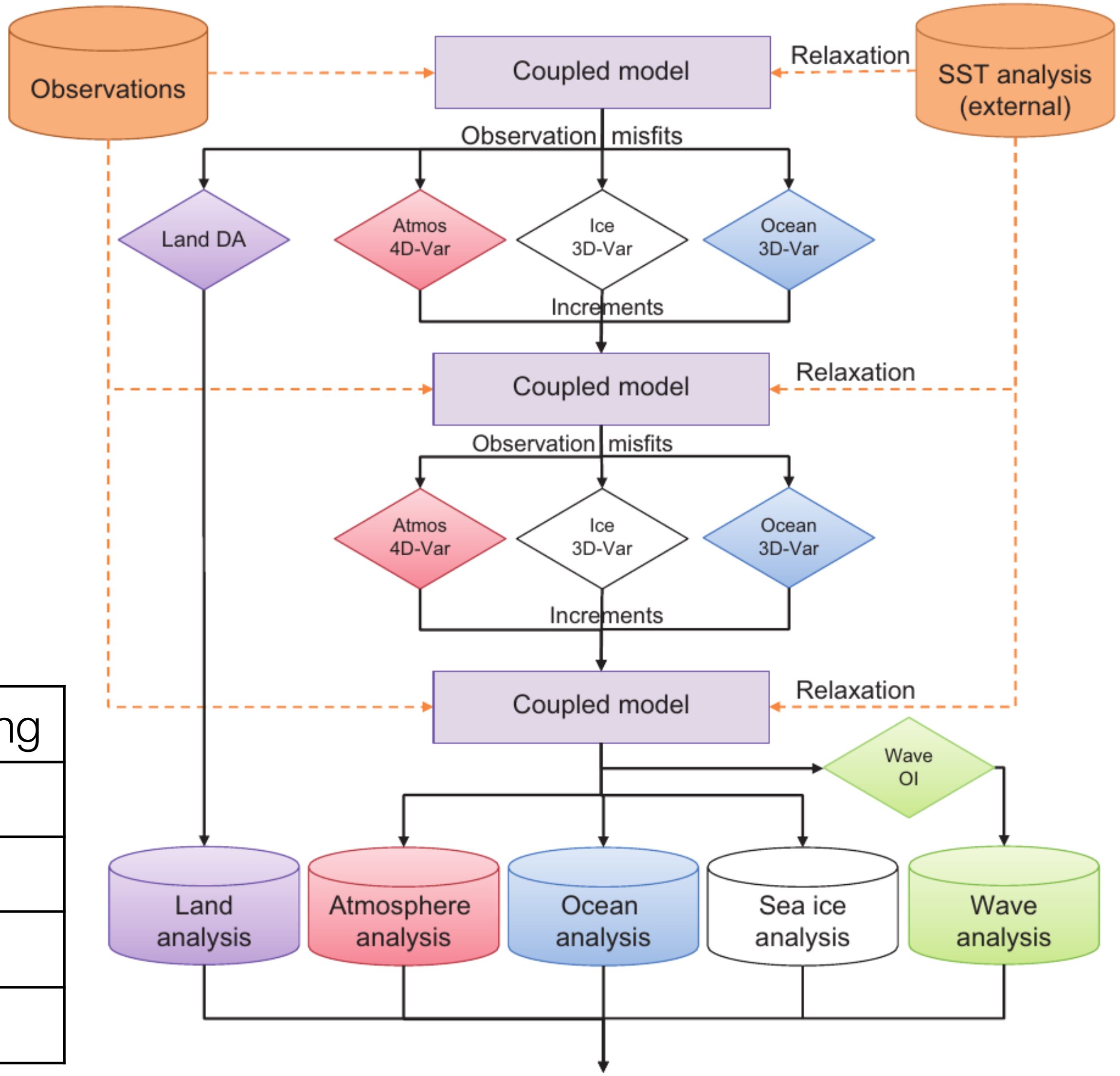
[M2-SCREAM water vapor before and after HTHH eruption; K. Wargan]

Targets: more coupled ocean-atmosphere reanalyses

CERA, CAFE60, toward ERA6 and MERRA-3

- Prior coupled reanalysis focused more on forecast initialization (NCEP CFSR / CFSv2)
- Strong coupling: data assimilation constraints affect atmosphere and ocean simultaneously
- Weak coupling: data assimilation constraints affect atmosphere and ocean separately, with indirect effects on the other
- Increasing use of ensemble approaches to better quantify uncertainty

Reanalysis	Period	Centre	Members	Coupling
CFSR	1979 – 2010	NCEP	1	weak
CERA-20C	1901 – 2010	ECMWF	10	weak
CERA-SAT	2008 – 2016	ECMWF	10	weak
CAFE60	1960 – 2021	CSIRO	96	strong



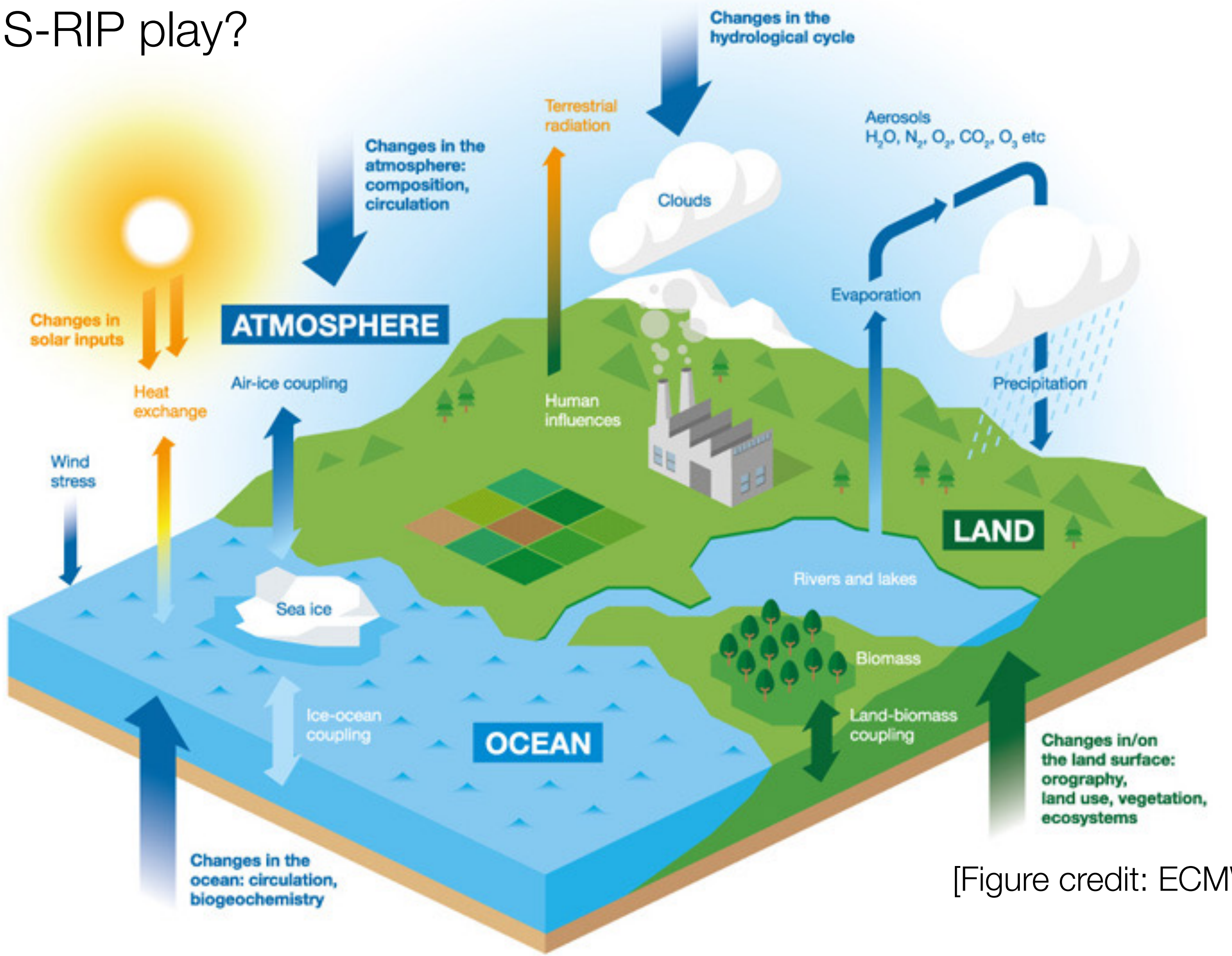
Long-term: toward reanalyses of the coupled Earth system

Key Questions:

- How do we deal with the ever-increasing volume of data?
- What roles can / should S-RIP play?

Example: US CLIVAR Workshop on Future Earth System Reanalyses (May 2022)

[conference webpage]



[Figure credit: ECMWF]

[recorded lectures]

A-RIP: seeking your participation!

APARC Reanalysis Intercomparison Project

We plan to:

- Continue to gather and share information on existing and near-future reanalysis products
- Continue communication with groups producing reanalyses and cooperate on evaluation & intercomparison
- Entrain folks who are interested in helping evaluate reanalyses, especially early career scientists
- Increase the visibility, accessibility, and impact of S-RIP outcomes

Emma Knowland
k.e.knowland@nasa.gov
S-RIP2/A-RIP planning for composition reanalyses; WMO GAFIS liaison

Kris Wargan
krzysztof.wargan-1@nasa.gov
S-RIP2/A-RIP planning for composition reanalyses

Sean Davis
sean.m.davis@noaa.gov
S-RIP2/A-RIP planning for composition reanalyses

We invite all who are interested in A-RIP to the workshop following QOS:
Boulder, CO 22-24 July
ECS event: 20-21 July

Felix Ploeger
f.ploeger@fz-juelich.de
S-RIP2/A-RIP planning for UTLS dynamic and composition studies

Moha Diallo
m.diallo@fz-juelich.de
outreach & capacity building; general planning; stratospheric dynamics

Patrick Martineau
pmartineau@jamstec.go.jp
data & diagnostics; general planning

[s-rip.github.io]

S-RIP2 leads:

Jonathon: jswright@tsinghua.edu.cn
Gloria: manney@nwra.com
Masatomo: fuji@ees.hokudai.ac.jp