RCEMIP: Moving from a single intercomparison to a framework for intercomparisons

<u>“Official” RCEMIP</u>

RCEMIP-I
- Uniform SST
- Wing et al. 2018, 2020…and many papers by many groups [see AGU special collection]

RCEMIP-II
- Prescribed sinusoidal SST (mock-Walker)
- Wing et al. 2024, in review

<u>RCEMIP Offshoots</u>

RCEMIP-ACI (Aerosol-Cloud Interactions)
- Led by Guy Dagan

RCEMIP-ROT (Rotating RCE on the Sphere)
- Some interest last year, but not enough to pursue at this time

RCEMIP-??

https://myweb.fsu.edu/awing/rcemip.html

RCEMIP-ACI

- Part of the GEWEX Aerosol Precipitation (GAP) initiative

- The simulation protocol is closely aligned with the RCEMIP protocol for CRMs, but with at least three different prescribed aerosol/cloud droplet concentrations.

- The aerosol concentrations affect only the cloud microphysics and not the radiation directly (as aerosol-radiation interactions are excluded).

- Most models have already uploaded their simulations. We expect a paper presenting the data (and making it publicly available) at the beginning of 2025.

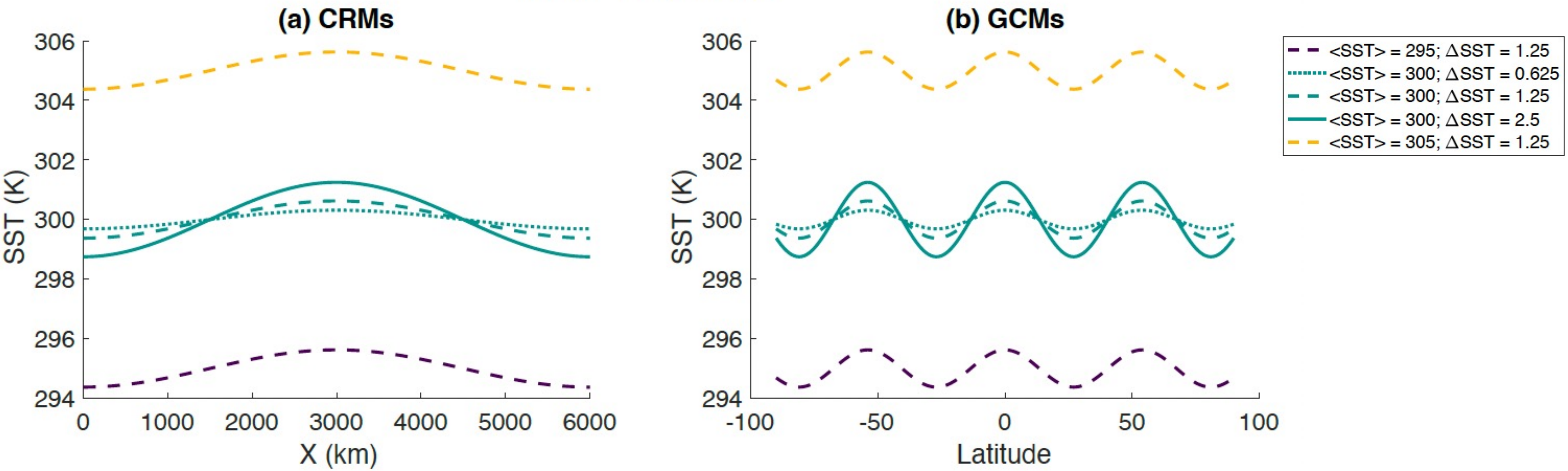
- For details, contact guy.dagan@mail.huji.ac.il

RCEMIP-ACI – model list

Model	Contributor	University
1. ICON	Corinna Hoose, Barthlott Christian	KIT
2. MicroHH	Tijhuis Mirjam	Wageningen University
3. DAM	David Romps	UC Berkeley
4. XSHiELD	Tristan Abbott	GFDL
5. WRF	Thara Prabhakaran, Gayatri Kulkarni	Indian Institute of Tropical Meteorology
6. MESONH	Jean-Pierre Chaboureau	University of Toulouse
7. SAM-M2005	Guy Dagan	HUJI
8. SAM-P3	Blaž Gasparini	UNIVIE
9. RAMS	Sue van den Heever, Leung Gabrielle	CSU
10. DALES	Fredrik Jansson	TU Delft

For details - guy.dagan@mail.huji.ac.il

RCEMIP-II Required Simulations



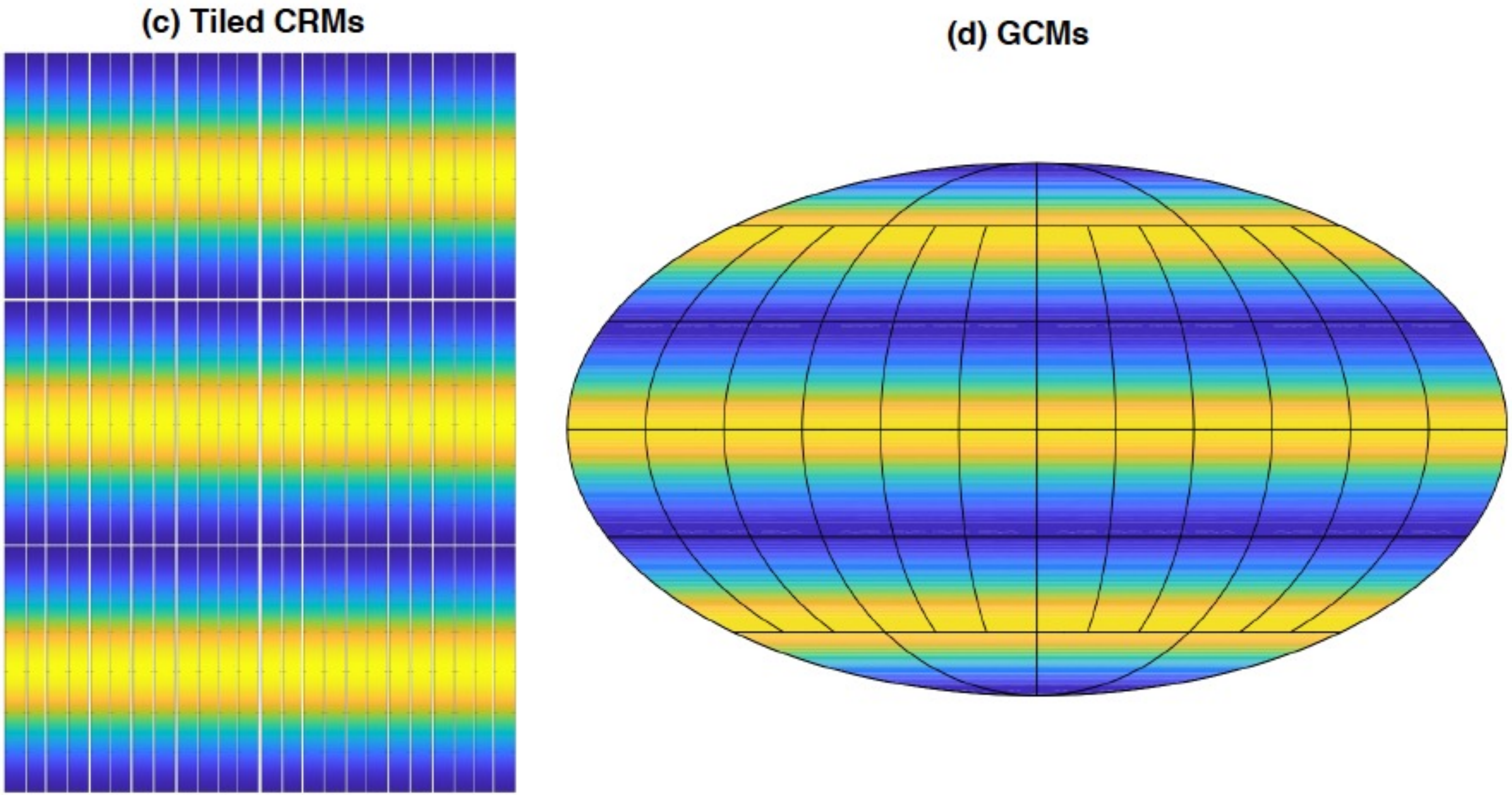
$$SST(x) = \langle SST \rangle - \frac{\Delta SST}{2} cos\left(\frac{2\pi x}{L_x}\right)$$

$\boldsymbol{\lambda}$ = L_x (domain length) ~6000 km

$$SST(\phi) = \langle SST \rangle + \frac{\Delta SST}{2} cos\left(\frac{360° \phi}{\lambda}\right)$$

$\boldsymbol{\lambda}$ = 54° to yield ~6000 km wavelength

Wing, A.A., L.G. Silvers, and K.A. Reed: RCEMIP-II: Mock-Walker Simulations as Phase II of the Radiative-Convective Equilibrium Model Intercomparison Project, Geosci. Model Dev. Discuss. [preprint], doi:10.5194/gmd-2023-235, in review.


(c) Tiled CRMs
(d) GCMs

RCEMIP-II Simulations

Wing, A.A., L.G. Silvers, and K.A. Reed: RCEMIP-II: Mock-Walker Simulations as Phase II of the Radiative-Convective Equilibrium Model Intercomparison Project, Geosci. Model Dev. Discuss. [preprint], doi:10.5194/gmd-2023-235, in review.

- Initialize from equilibrium RCE_small sounding at corresponding <SST>
- Run for 200 days* (CRMs) or 3 years (GCMs)
- Other than SST boundary condition, set-up identical to RCE_large
    - CRMs: Get as close as possible to Lx = 6000 km

<u>Optional Experiments</u>

- Additional deltaSST

- Mechanism Denial/Simplification Experiments?
    - Fixed radiation (specified profile, uniform in space and time)?
    - Capped surface fluxes?

Required Experiments	$\langle SST \rangle$	ΔSST
`MW_295dT1p25`	295 K	1.25 K
`MW_300dT0p625`	300 K	0.625 K
`MW_300dT1p25`	300 K	1.25 K
`MW_300dT2p5`	300 K	2.5 K
`MW_305dT1p25`	305 K	1.25 K

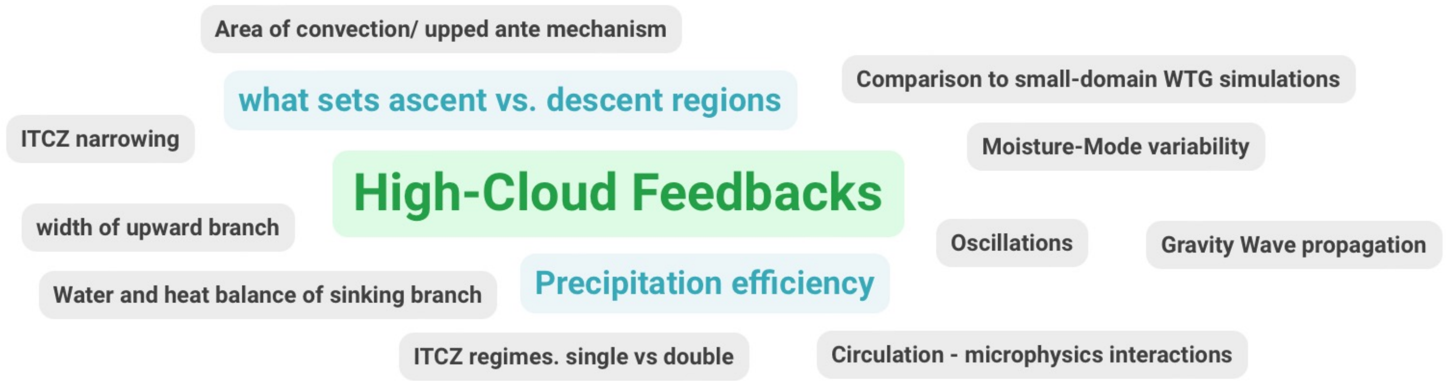
Optional Experiments	$\langle SST \rangle$	ΔSST
`MW_295dT0p625`	295 K	0.625 K
`MW_295dT2p5`	295 K	2.5 K
`MW_305dT0p625`	305 K	0.625 K
`MW_305dT2p5`	305 K	2.5 K

RCEMIP-II Objectives

RCEMIP-II Objectives

1. RCEMIP-I objectives in context of SST-forced circulation
   a) Robustness of climate state
   b) Response of clouds to warming and climate sensitivity
   c) Dependence of convective aggregation on temperature
2. Physical mechanisms leading to low-frequency oscillations and their ∇SST dependence
3. Development of stacked overturning circulations
4. Transition between regimes

Other ideas and interest for analysis?



https://app.sli.do/event/rCrLRqQTv6Y8qXxmMDyPch

RCEMIP-II Output Notes

- For relative humidity & saturated water vapor path: compute the saturation with respect to liquid for temperatures above freezing and with respect to ice for temperatures below freezing.

- 0D & 2D vertically integrated data: clwvi is cloud ice + cloud liquid
- 1D & 3D data: clw is cloud liquid ONLY

- CRM threshold for cloud fraction: mixing ratio of the total cloud condensate (cloud liquid water + cloud ice) is greater than 1×10^{-5} g g^{-1}

- clisccp: listed in Table with 3D data, but this is a 2D CTP-tau histogram at each grid point and time…or should this be averaged in time?

- Some new *optional* output

RCEMIP-II Output

compute the saturation
with respect to liquid for temperatures above
freezing and with respect to ice for temperatures
below freezing.

clwvi_avg is cloud ice + cloud liquid

Table A1. 0D hourly-averaged variables (t). Italicized variables are *not* standard CMIP output.

Variable Name	Description	Units
pr_avg	domain avg. surface precipitation rate	kg m^{-2} s^{-1}
hfls_avg	domain avg. surface upward latent heat flux	W m^{-2}
hfss_avg	domain avg. surface upward sensible heat flux	W m^{-2}
prw_avg	domain avg. water vapor path	kg m^{-2}
sprw_avg	domain avg. saturated water vapor path	kg m^{-2}
clwvi_avg	domain avg. condensed water path (cloud ice + cloud liquid)	kg m^{-2}
clivi_avg	domain avg. ice water path (cloud ice)	kg m^{-2}
rlds_avg	domain avg. surface downwelling longwave flux	W m^{-2}
rlus_avg	domain avg. surface upwelling longwave flux	W m^{-2}
rsds_avg	domain avg. surface downwelling shortwave flux	W m^{-2}
rsus_avg	domain avg. surface upwelling shortwave flux	W m^{-2}
rsdscs_avg	domain avg. surface downwelling shortwave flux - clear sky	W m^{-2}
rsuscs_avg	domain avg. surface upwelling shortwave flux - clear sky	W m^{-2}
rldscs_avg	domain avg. surface downwelling longwave flux - clear sky	W m^{-2}
rluscs_avg	domain avg. surface upwelling longwave flux - clear sky	W m^{-2}
rsdt_avg	domain avg. TOA incoming shortwave flux	W m^{-2}
rsut_avg	domain avg. TOA outgoing shortwave flux	W m^{-2}
rlut_avg	domain avg. TOA outgoing longwave flux	W m^{-2}
rsutcs_avg	domain avg. TOA outgoing shortwave flux - clear sky	W m^{-2}
rlutcs_avg	domain avg. TOA outgoing longwave flux -clear sky	W m^{-2}

Table A2. 1D hourly-averaged variables (z,t). Italicized variables are *not* standard CMIP output.

compute the saturation with respect to liquid for temperatures above freezing and with respect to ice for temperatures below freezing.

clw_avg is cloud liquid ONLY

mixing ratio of the total cloud condensate (cloud liquid water + cloud ice) is greater than 1 x 10^{-5} g g^{-1}

Variable Name	Description	Units
ta_avg	domain avg. air temperature profile	K
ua_avg	domain avg. eastward wind profile	m s^{-1}
va_avg	domain avg. northward wind profile	m s^{-1}
hus_avg	domain avg. specific humidity profile	kg/kg
hur_avg	domain avg. relative humidity profile	%
clw_avg	domain avg. mass fraction of cloud liquid water profile	kg/kg
cli_avg	domain avg. mass fraction of cloud ice profile	kg/kg
plw_avg	domain avg. mass fraction of precipitating liquid water profile	kg/kg
pli_avg	domain avg. mass fraction of precipitating ice profile	kg/kg
theta_avg	domain avg. potential temperature profile	K
thetae_avg	domain avg. equivalent potential temperature profile	K
tntrs_avg	domain avg. shortwave radiative heating rate profile	K s^{-1}
tntrl_avg	domain avg. longwave radiative heating rate profile	K s^{-1}
tntrscs_avg	domain avg. shortwave radiative heating rate profile - clear sky	K s^{-1}
tntrlcs_avg	domain avg. longwave radiative heating rate profile - clear sky	K s^{-1}
cldfrac_avg	global cloud fraction profile	

Table A3. 2D hourly averaged variables (x,y,t). Italicized variables are *not* standard CMIP output. Bolded variables are a new request compared to RCEMIP-I. Variables with a (!) symbol are required only for models with parameterized convection.

Variable Name	Description	Units
pr	surface precipitation rate	kg m^{-2} s^{-1}
hfls	surface upward latent heat flux	W m^{-2}
hfss	surface upward sensible heat flux	W m^{-2}
rlds	surface downwelling longwave flux	W m^{-2}
rlus	surface upwelling longwave flux	W m^{-2}
rsds	surface downwelling shortwave flux	W m^{-2}
rsus	surface upwelling shortwave flux	W m^{-2}
rsdscs	surface downwelling shortwave flux - clear sky	W m^{-2}
rsuscs	surface upwelling shortwave flux - clear sky	W m^{-2}
rldscs	surface downwelling longwave flux - clear sky	W m^{-2}
rluscs	surface upwelling longwave flux - clear sky	W m^{-2}
rsdt	TOA incoming shortwave flux	W m^{-2}
rsut	TOA outgoing shortwave flux	W m^{-2}
rlut	TOA outgoing longwave flux	W m^{-2}
rsutcs	TOA outgoing shortwave flux - clear sky	W m^{-2}
rlutcs	TOA outgoing longwave flux -clear sky	W m^{-2}
prw	water vapor path	kg m^{-2}
sprw	saturated water vapor path	kg m^{-2}
clwvi	condensed water path (cloud ice + cloud liquid)	kg m^{-2}
clivi	ice water path (cloud ice)	kg m^{-2}
psl	sea level pressure	Pa
tas	2m air temperature	K
tabot	air temperature at lowest model level	K
uas	10m eastward wind	m s^{-1}
vas	10m northward wind	m s^{-1}
uabot	eastward wind at lowest model level	m s^{-1}
vabot	northward wind at lowest model level	m s^{-1}
wa500 or *wap500*	vertical velocity or omega at 500 hPa	m s^{-1} or Pa s^{-1}
cl[!]	total cloud fraction of grid column	
pr_conv[!]	surface convective precipitation rate	kg m^{-2} s^{-1}
albisccp[!]	ISCCP mean cloud albedo	
cltisccp[!]	ISCCP total cloud cover	%
pctisccp[!]	ISCCP mean cloud top pressure	Pa

compute the saturation with respect to liquid for temperatures above freezing and with respect to ice for temperatures below freezing.

clwvi is cloud ice + cloud liquid

Table A4. 3D instantaneous 6-hourly variables (x,y,z,t).Italicized variables are *not* standard CMIP output. Bolded variables are a new request compared to RCEMIP-I. Variables with a (!) symbol are required only for models with parameterized convection.

Variable Name	Description	Units
clw	mass fraction of cloud liquid water	g/g
cli	mass fraction of cloud ice	g/g
plw	mass fraction of precipitating liquid water	g/g
pli	mass fraction of precipitating ice	g/g
ta	air temperature	K
ua	eastward wind	m s^{-1}
va	northward wind	m s^{-1}
hus	specific humidity	g/g
wa or wap	vertical velocity or omega	m s^{-1} or Pa s^{-1}
pa or zg	pressure or geopotenial height	Pa or m
tntrs	tendency of air temperature due to shortwave radiative heating	K s^{-1}
tntrl	tendency of air temperature due to longwave radiative heating	K s^{-1}
tntrscs	tendency of air temperature due to shortwave radiative heating - clear sky	K s^{-1}
tntrlcs	tendency of air temperature due to longwave radiative heating - clear sky	K s^{-1}
cldfrac!	cloud fraction	
mc!	convective mass flux	kg m^{-2} s^{-1}
tntc!	tendency of air temperature due to moist convection	K s^{-1}
clisccp!	ISCCP cloud area percentage in optical depth and pressure bins	%

clw is cloud liquid ONLY

2D CTP-tau histogram at each grid point and time [move to Table A3?]

…or averaged in time?

Table A5. Optional output variables. Italicized variables are *not* standard CMIP output. Bolded variables are a new request compared to RCEMIP-I.

Variable Name	Description	Units
6-hourly instantaneous 3-D variables (x,y,z,t)		
tntm	tendency of air temperature due to microphysical latent heating	K s^{-1}
reffclw	effective radius of cloud liquid water (in-cloud)	μm
reffcli	effective radius of cloud ice (in-cloud)	μm
cdnc	number concentration of cloud liquid water particles (in-cloud)	cm^{-3}
icnc	number concentration of cloud ice particles (in-cloud)	cm^{-3}
30-minute instantaneous 2-D variables (x,y,t)		
rlut_inst	TOA outgoing longwave flux	W m^{-2}
pr_inst	surface precipitation rate	kg m^{-2} s^{-1}
Hourly 2-D variables (x,y,t)		
fmse	mass-weighted vert. integral of FMSE	J m^{-2}
advfmse	mass-weighted vert. integral of advective tendenc[illegible]	[illegible]
tnfmse	tendency of mass-weighted vert. integral of FMSE	[illegible]
tnfmsevar	tendency of spatial variance of mass-weighted ver[illegible]	[illegible]
crvi	mass-weighted vert. integral of gross condensation rate	kg m^{-2} s^{-1}

vertical integral of the negative part of the microphysical tendency of water vapor, *if* water vapor is a prognostic variable

RCEMIP-II Data Upload

DKRZ Swiftbrowser: Upload via swift command line client. Download via wget

Current pseudofolder Structure for RCEMIP-I

MODEL 1
 > EXPERIMENT 1
    > 0D
    > 1D
    > 2D
    > 3D
 > EXPERIMENT 2
    > 0D
    > 1D
    > 2D
    > 3D
…

MODEL 2
 …

Keep this for RCEMIP-II, or instead use…?

EXPERIMENT 1
>0D
   > MODEL 1
   > MODEL 2
   …
>1D

EXPERIMENT 2
>0D
   > MODEL 1
   > MODEL 2
   …
>1D

Which output structure would you prefer?

Current structure (MODELS/EXPERIMENTS/DIMENSIONS/DATA) 22%

New structure (EXPERIMENTS/DIMENSIONS/MODELS/DATA) 11%

Allison makes a wget script to do either option 67%

RCEMIP-II Data Access

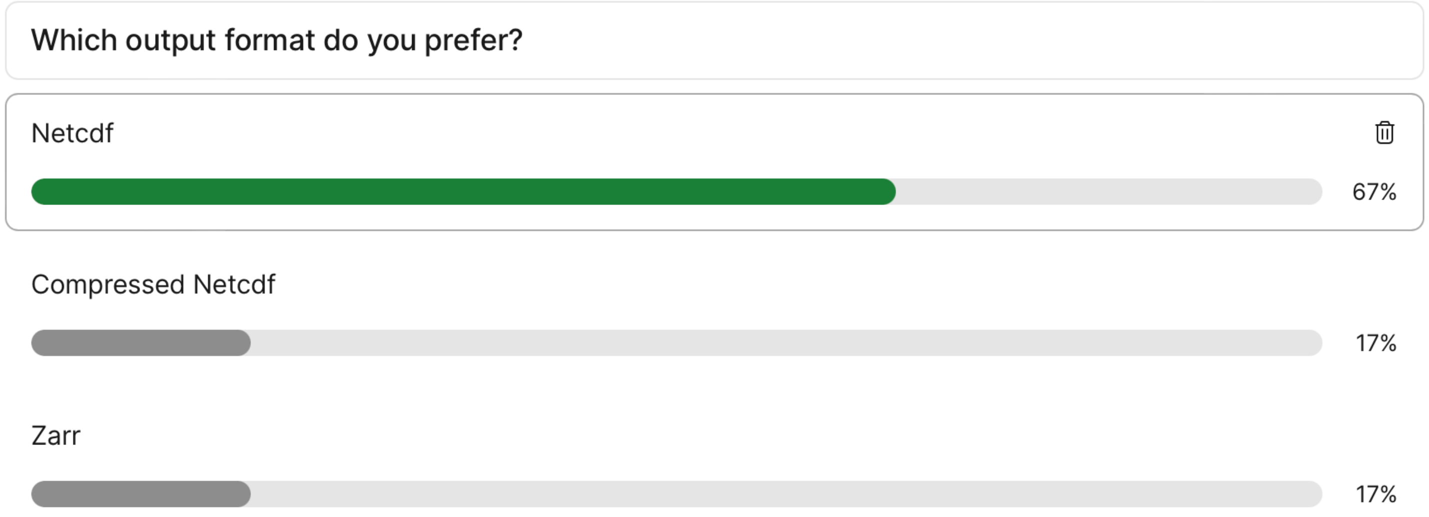
DKRZ Swiftbrowser: Upload via swift command line client. Download via wget

Access without downloading via intake catalog? Experimental with netcdf on swiftbrowser.

Output format:
Netcdf?
Zarr?
Standard netcdf compression?

Timeframe:

- Upload by end of summer
- Accessible to model contributors only until initial results paper submitted
- Publicly available when initial results paper (all model contributors as coauthors) submitted (~1 year?)



RCEMIP-I Data

How frequently is the data accessed?

- Fill out form on RCEMIP website when you download/use the data!
- About 25 people have filled out the form (but I know there are others who have used it without filling out the form)

Does it need to stay on the swiftbrowser, or could it be archived to WDC?

- **DKRZ will ensure that the handle will always resolve to the RCEMIP data.**
- Archive most of the data on WDC but retain a subset of the RCEMIP-I data on the swiftbrowser (or new DKRZ storage cloud?).
    - The post-processed A-Statistics, 0D, and 1D files get the most use.

https://myweb.fsu.edu/awing/rcemip.html

RCEMIP-II Participants

Model Type	Model	
CRM	DALES	Dutch Atmospheric Large Eddy Simulation (Heus et al., 2010)
CRM	DAM	Das Atmosphaerisch Modell (Romps, 2008)
CRM	FV3	GFDL-FV3 CRM (Zhou et al., 2019)
CRM	ICON	ICOsahedral Nonhydrostatic Model - Sapphire (Hohenegger et al., 2023)
CRM	MESO-NH	MESO-NH v5.6 (Lac et al., 2018)
CRM	UKMO-RA1-T	UK Met Office Idealized Model v11.0 (Stratton et al., 2018)
CRM	RAMS	Regional Atmospheric Modeling System (Cotton et al., 2003)
CRM	SAM-1MOM	System for Atmospheric Modeling, 1-moment microphysics (Khairoutdinov and Randall, 2003)
CRM	SAM-M2005	System for Atmospheric Modeling, M2005 microphysics (Morrison et al., 2005)
CRM	SAM-P3ice	System for Atmospheric Modeling, P3ice microphysics (Morrison and Milbrandt, 2015; Gasparini et al., 2022)
CRM	SCALE	Scalable Computing for Advanced Library and Environment v5.2.5 (Nishizawa et al., 2015; Sato et al., 2015)
CRM	SCREAMv0	Simple Cloud-Resolving E3SM Atmosphere Model (Caldwell et al., 2021; Bogenschutz et al., 2023)
CRM	SNAP	Simulating Nonhydrostatic Atmosphere on Planets (Li and Chen, 2019)
CRM	VVM	Vector Vorticity Model (Wu et al., 2019)
GCRM	ICON	ICOsahedral Nonhydrostatic Model - Sapphire (Hohenegger et al., 2023)
GCRM	NICAM	Non-hydrostatic Icosahedral Atmospheric Model v16.3 (Satoh et al., 2014)
GCRM	SAM	Global System for Atmospheric Modeling (Khairoutdinov et al., 2022)
GCM	CAM5	Community Atmosphere Model version 5 (Neale et al., 2012)
GCM	CAM6	Community Atmosphere Model version 6 (Danabasoglu et al., 2020)
GCM	CNRM-CM6	CNRM-CM6-1 - Atmosphere component (Roehrig and coauthors, 2020; Voldoire et al., 2019)
GCM	EXOCUBED	ExoCubed (Chen and Li, 2024)
GCM	E3SM-MMFv2	Super-parameterized Energy Exascale Earth System Model (Hannah et al., 2020)
GCM	FV3-AM4	GFDL-FV3 with AM4 Physics (Zhao et al., 2018a, b)
GCM	IPSL-CM6	LMDZ6A version (Hourdin and coauthors, 2020)
GCM	MIROC6	Model for Interdisciplinary Research on Climate (Tatebe et al., 2019)
GCM	SP-CAM	Super-Parameterized Community Atmosphere Model (Randall et al., 2016)
GCM	UKMO-GA7.1	Met Office Unified Model Global Atmosphere v7.1 (Walters et al., 2019)

Contact me (awing@fsu.edu) if you are interested in contributing! Simulations due end of summer.