

Radiative Transfer for Energetics

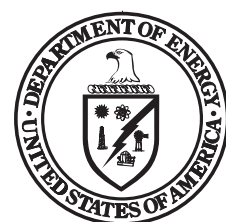
Rapid Radiative Transfer Model
- for GCMs - Parallel

RTE-RRTMGP in CAM implementation status

Brian Medeiros

Most of the 2023-2024 work done by Brian Eaton and Jian Sun,
with previous input and help from: Isaac Davis, Courtney Peverley, Jiang Zhu,
+ EarthWorks SE group, & R. Pincus

AMWG, January 2024



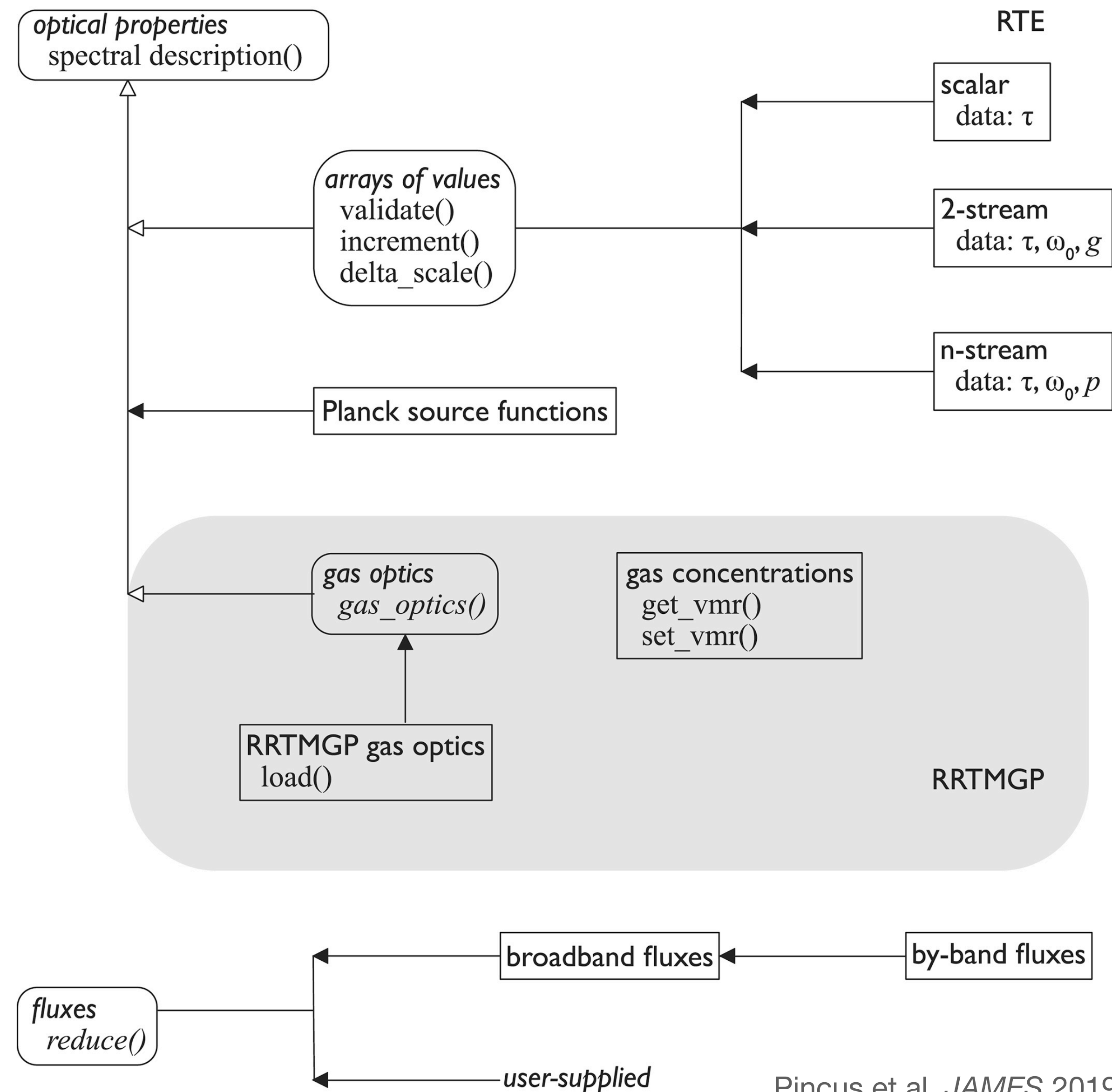
U.S. DEPARTMENT OF
ENERGY

Office of
Science

catalyst

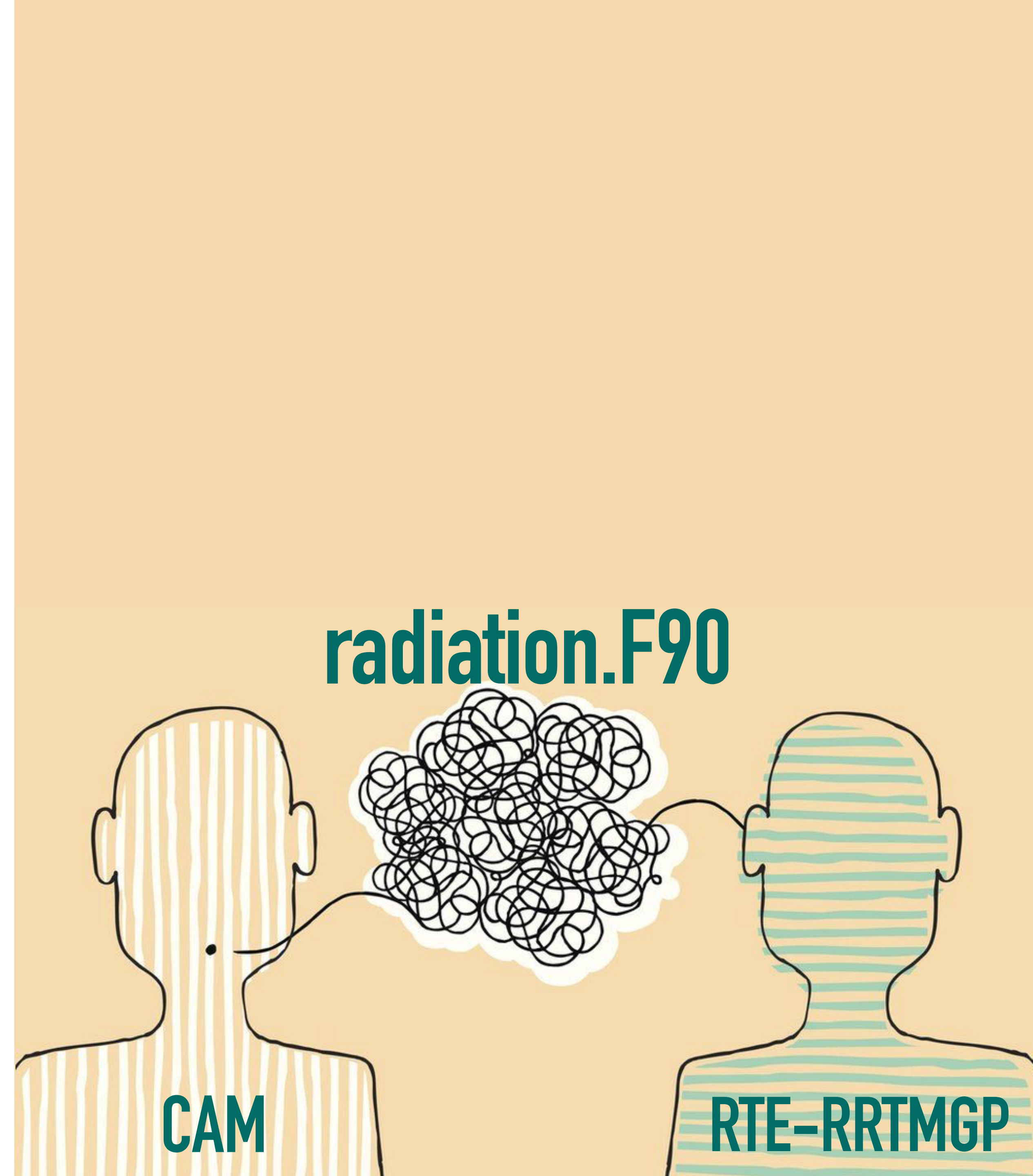
What & Why of RRTMGP

- ▶ Rewrite of RRTMG (Fortran 2003)
 - ▶ plane-parallel, correlated-k, 2-stream RTM
 - ▶ uses classes to control information passing
 - ▶ **no assumption of vertical ordering**
 - ▶ **updated spectroscopy**
 - ▶ Shortwave solver:
 $f(\mathbf{K}_{SW}, \text{insolation}(\lambda), \alpha_{\text{direct}}, \alpha_{\text{diffuse}},)$
 - ▶ Longwave solver:
 $f(\mathbf{K}_{LW}, B(\lambda, \text{lev}), \epsilon_{\text{sfc}})$
- ▶ Added capabilities
 - ▶ GPU
 - ▶ CCPP



What's involved

- ▶ Bring in RTE-RRTMGP as an external
- ▶ new interface between CAM and RTE-RRTMGP
- ▶ Mainly this is **radiation.F90**, but with a bunch of supporting changes:
 - rrtmgp_inputs.F90 (new, similar to rrtmg_state.F90)
 - radconstants.F90



Current status

- RTE-RRTMGP v1.7 (released 27 Nov 2023)
- RRTMGP-data v1.8 (released 27 Nov 2023)
- PR is in process
- `xmlchange --append CAM_CONFIG_OPTS="-rad rrtmgp"`
- COSP available
- New test simulations
 - FLTHIST: 1999-2006
 - FMTHIST: 1996-2002

interface structure

all the subroutines in radiation module

radiation.F90

radiation_readnl
radiation_register
radiation_init
radiation_define_restart
radiation_write_restart
radiation_read_restart

radiation_tend

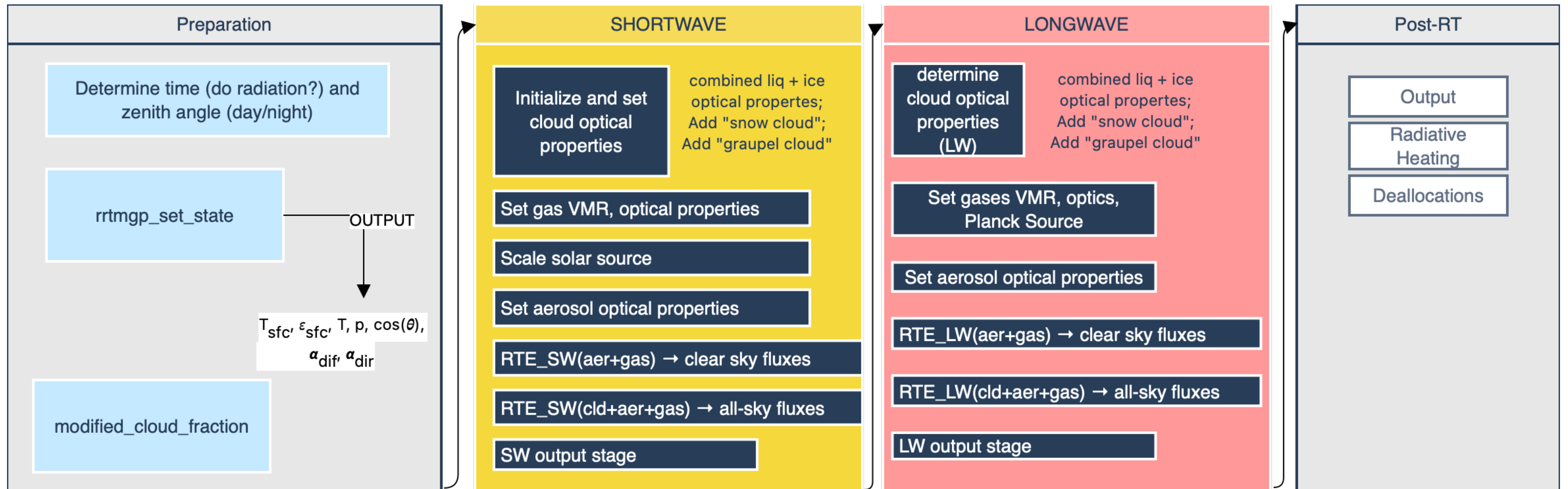
>set_sw_diags
>set_lw_diags
>heating_rate
radiation_output_sw
radiation_output_cld
radiation_output_lw
coefs_init
initialize_rrtmgp_fluxes
reset_fluxes
free_optics_sw
free_optics_lw
free_fluxes
modified_cloud_fraction
stop_on_err

mcica_subcol_gen.F90

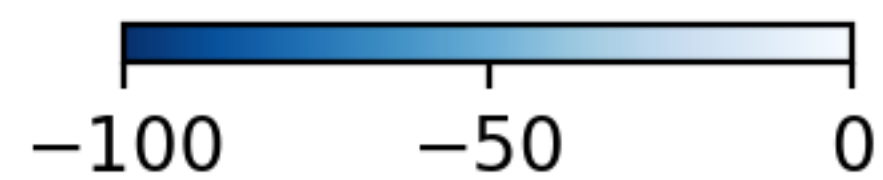
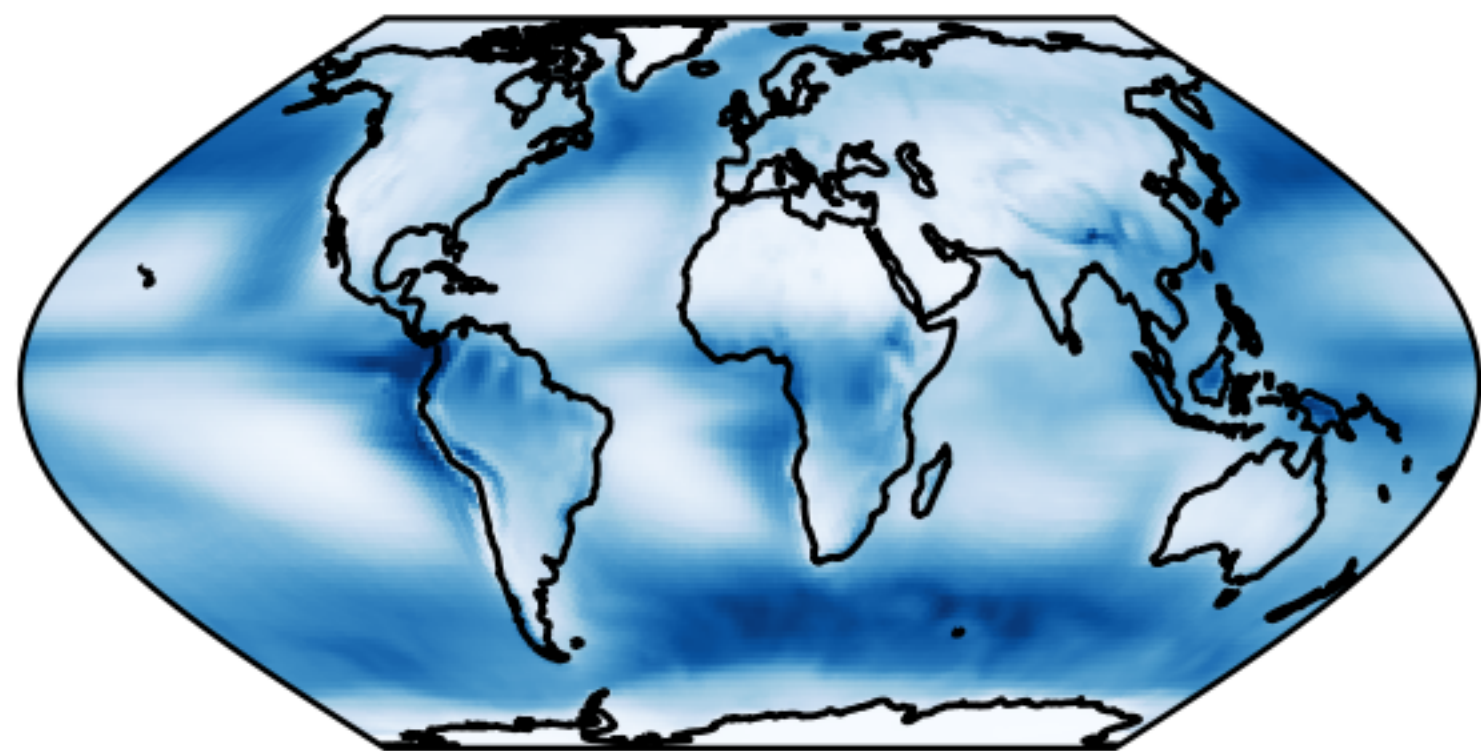
radconstants.F90

rrtmgp_inputs.F90

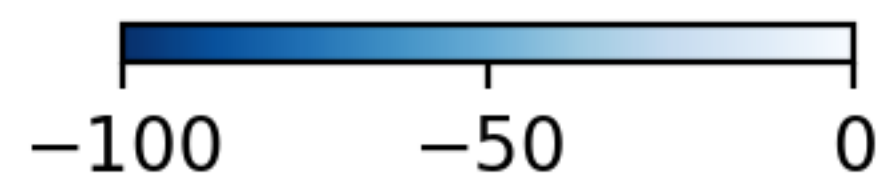
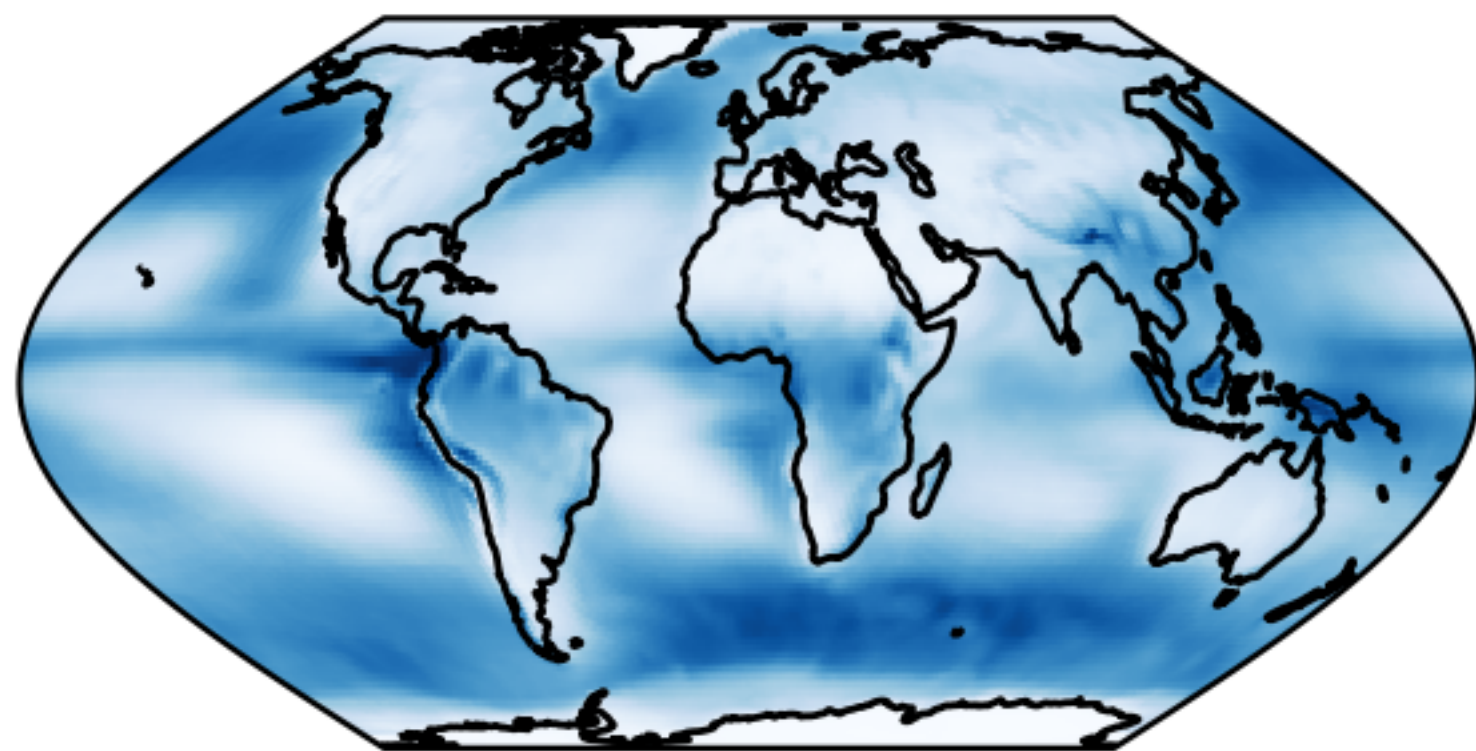
radiation_tend



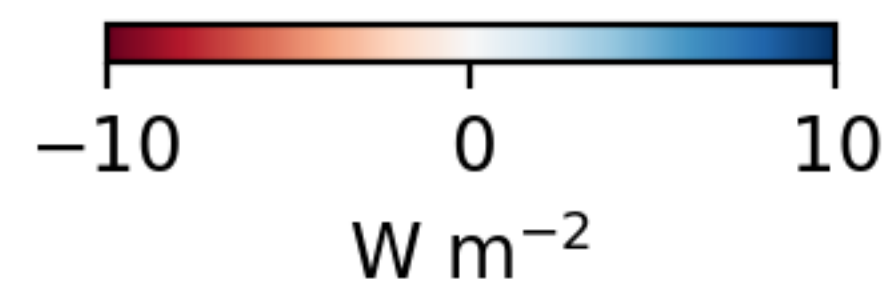
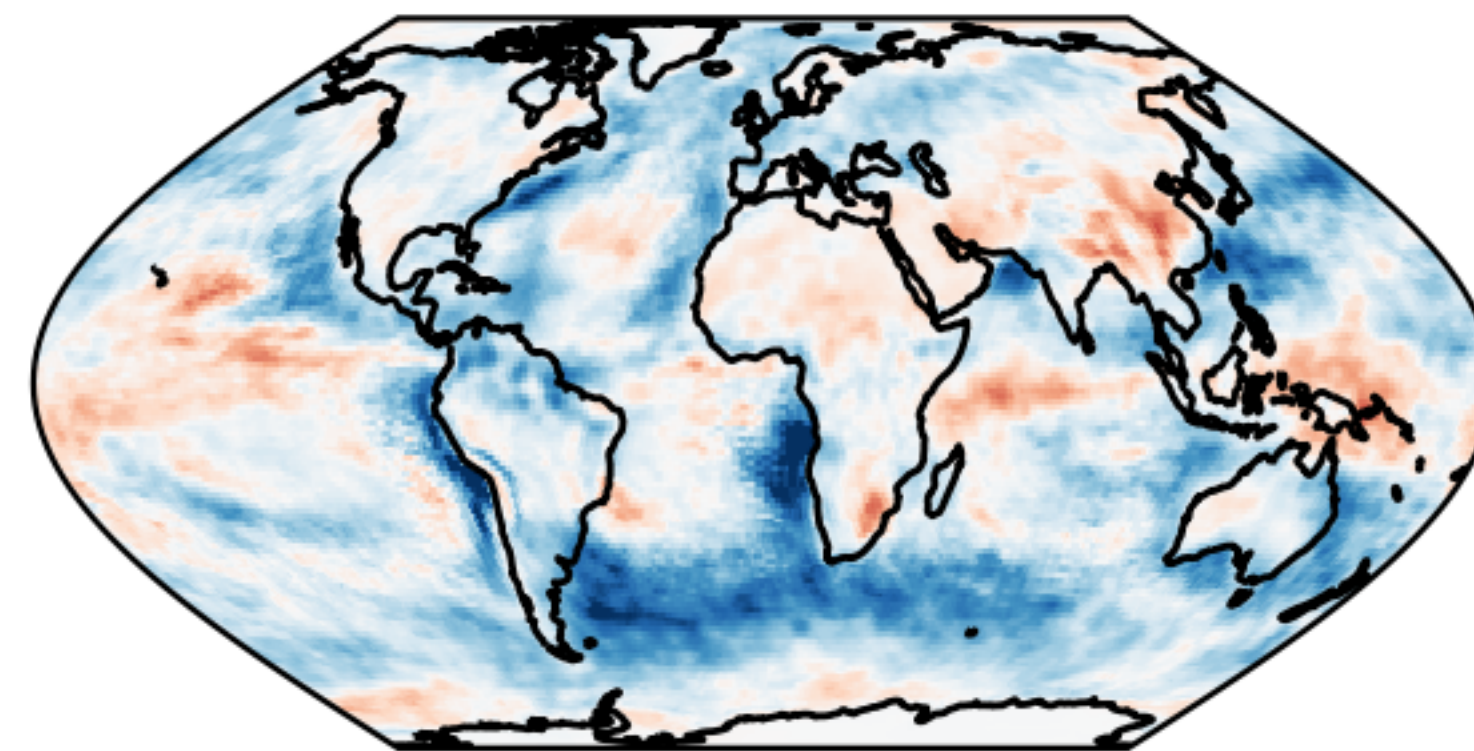
RRTMG, L58, SWCF (avg: -41.95)



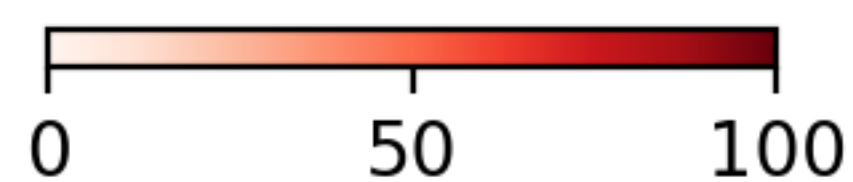
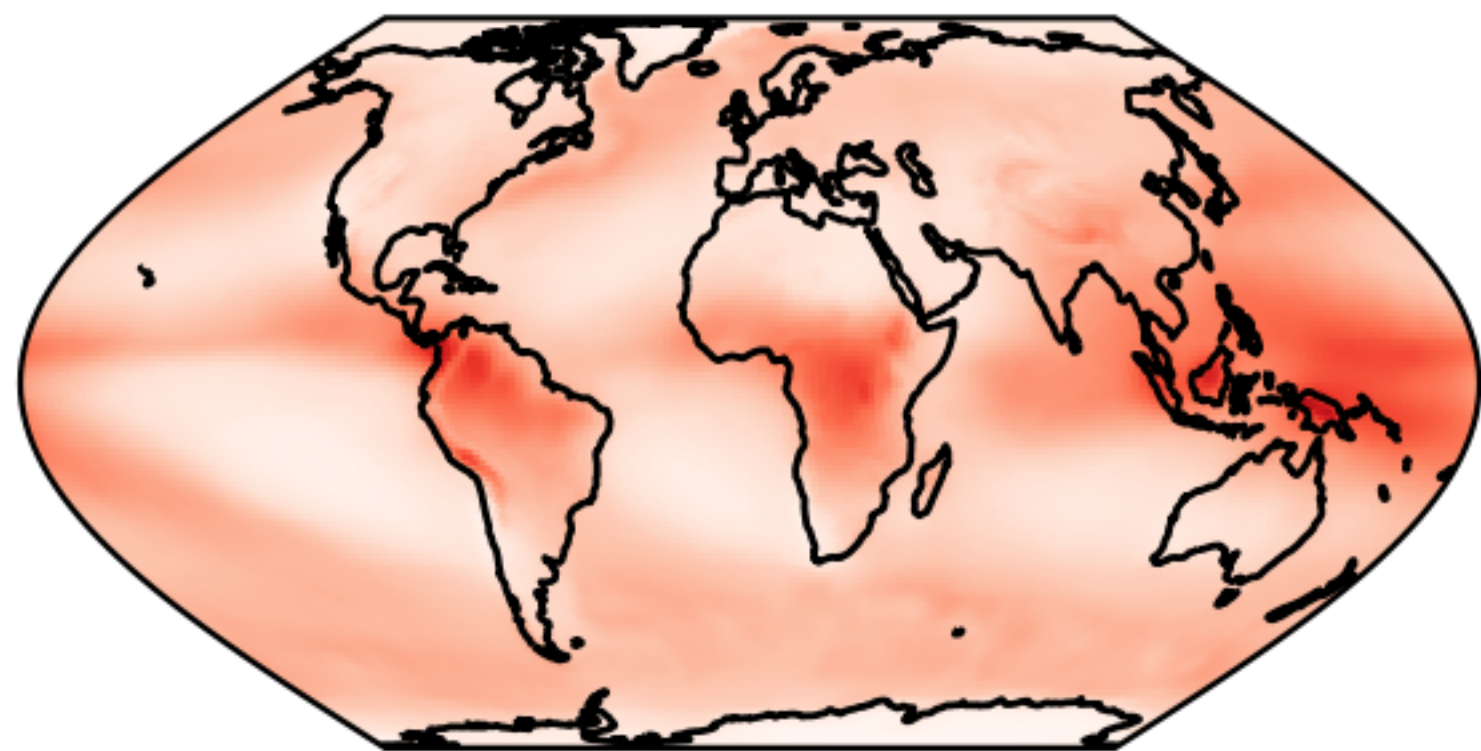
RRTMGP, L58, SWCF (avg: -40.45)



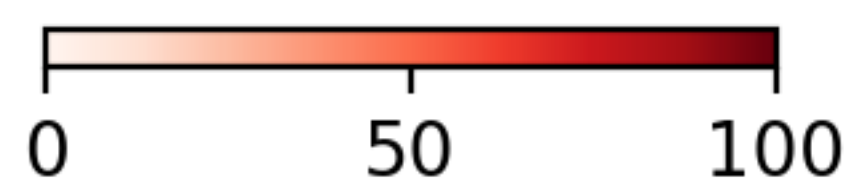
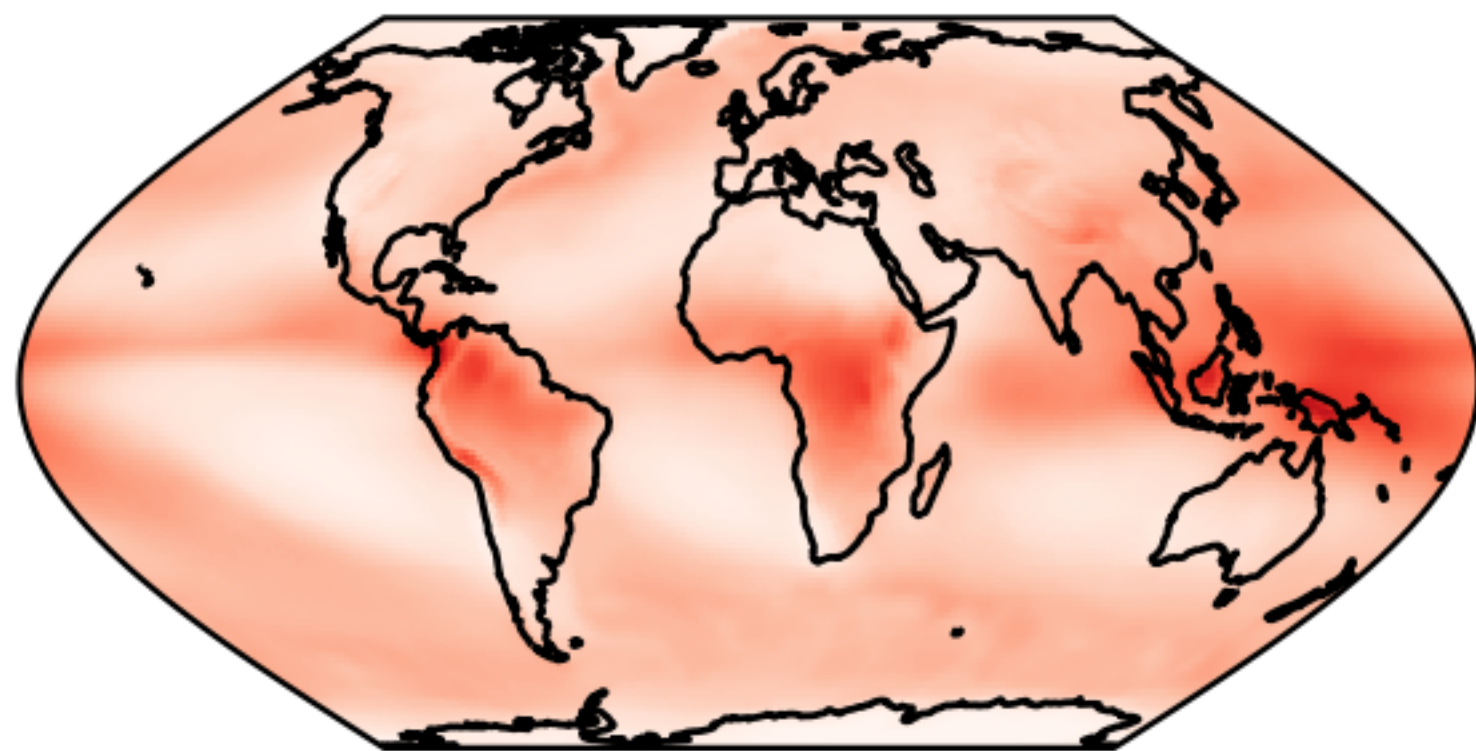
Difference (avg: 1.50)



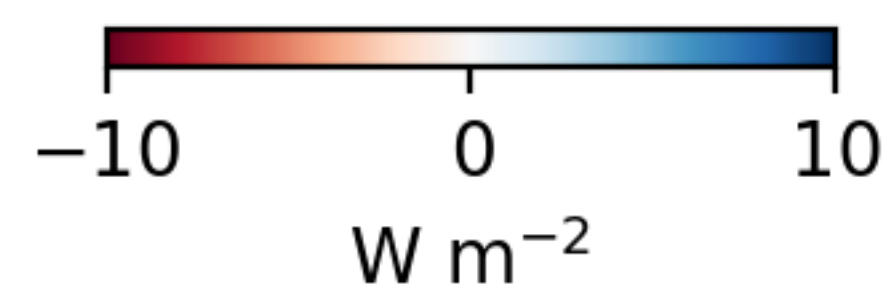
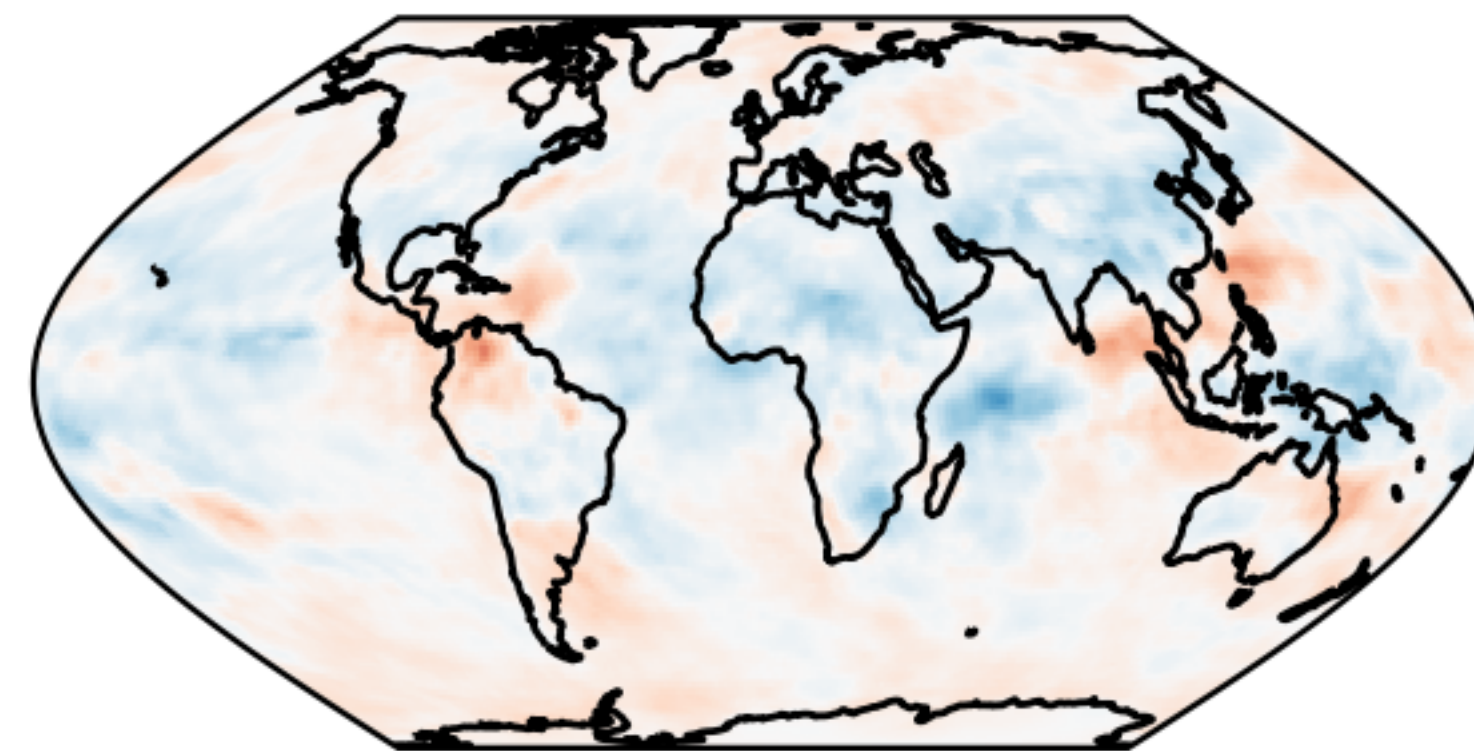
RRTMG, L58, LWCF (avg: 22.52)



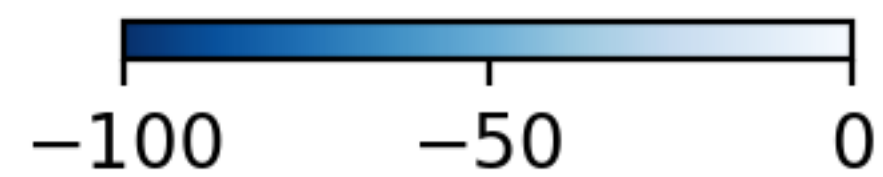
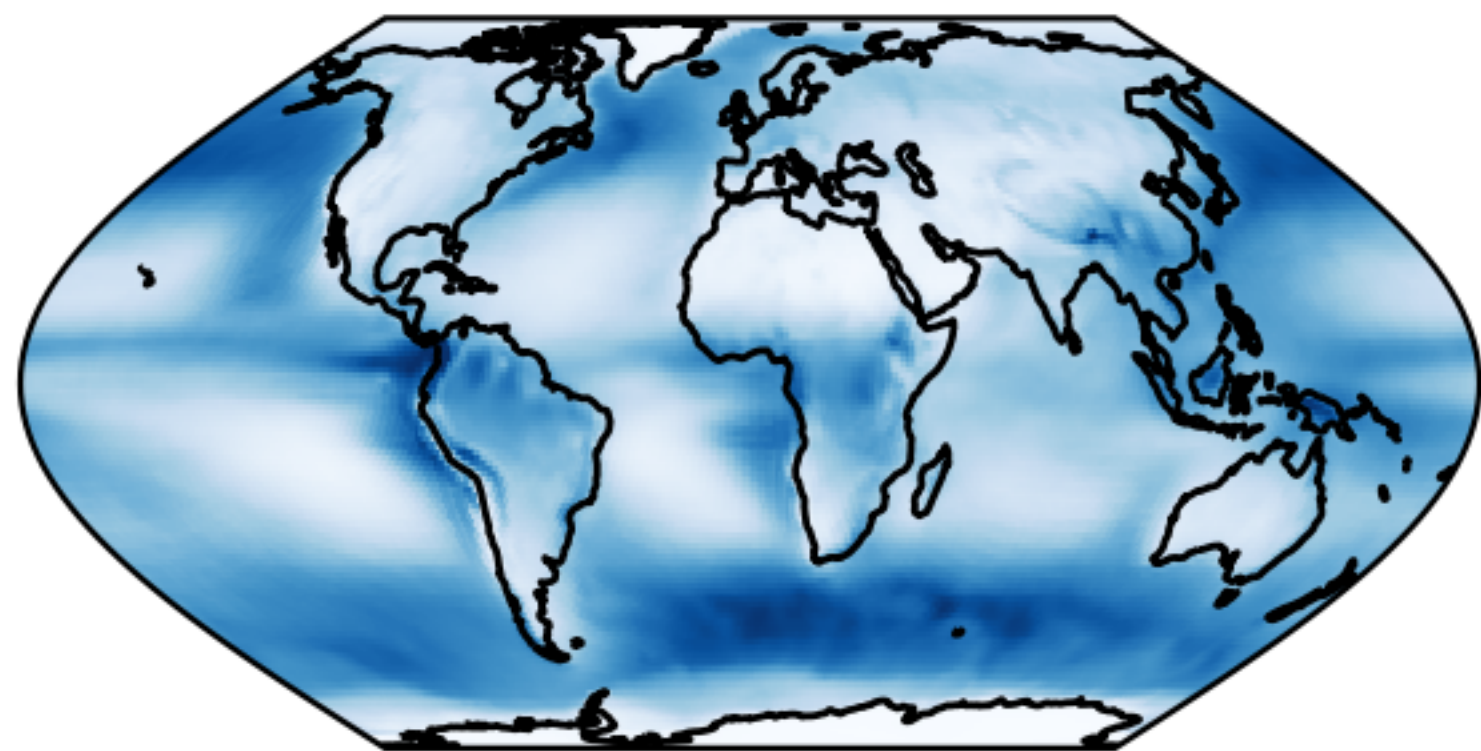
RRTMGP, L58, LWCF (avg: 22.69)



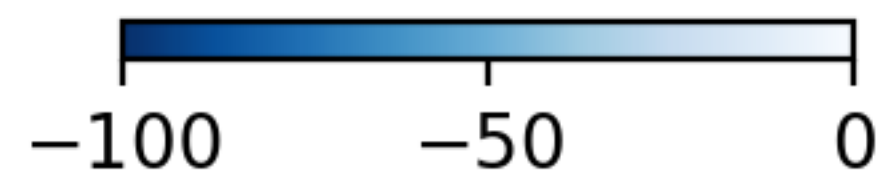
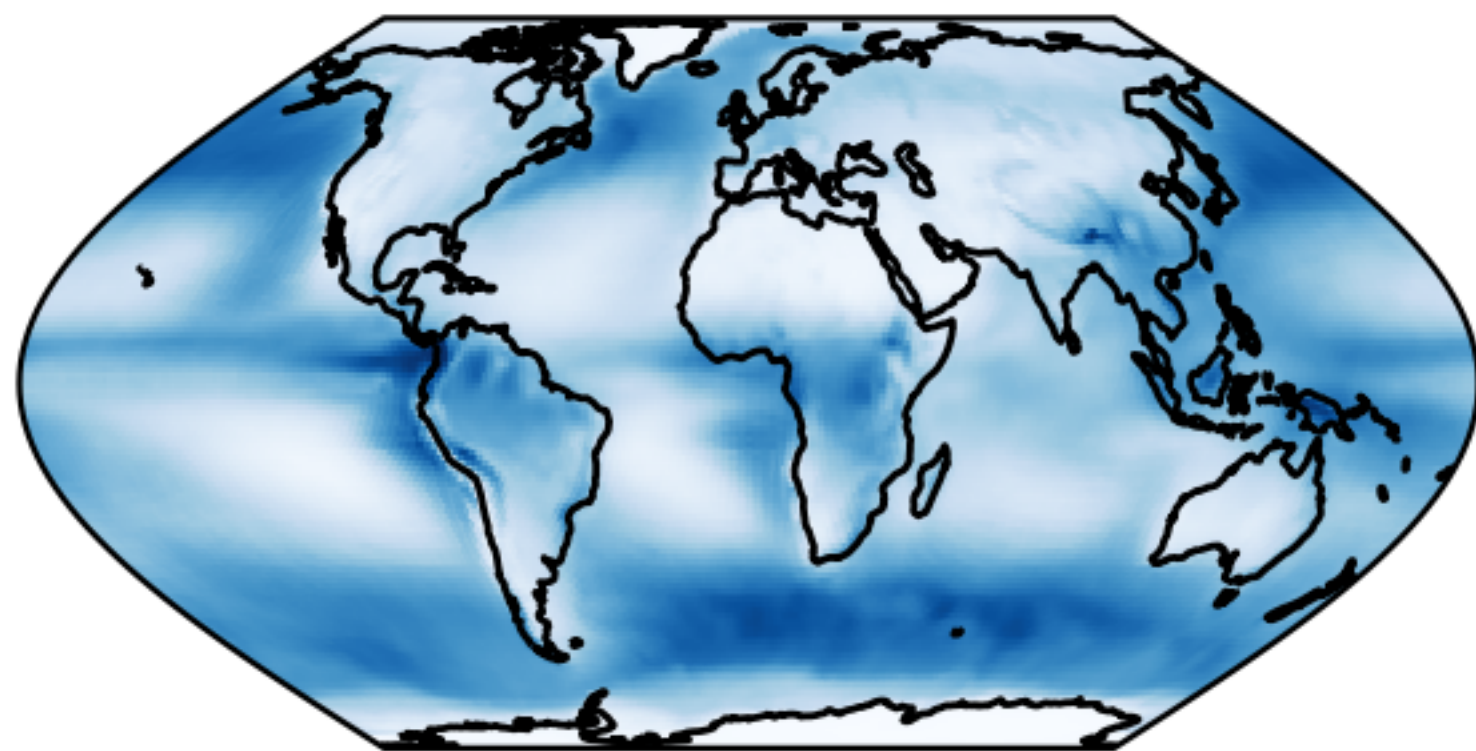
Difference (avg: 0.17)



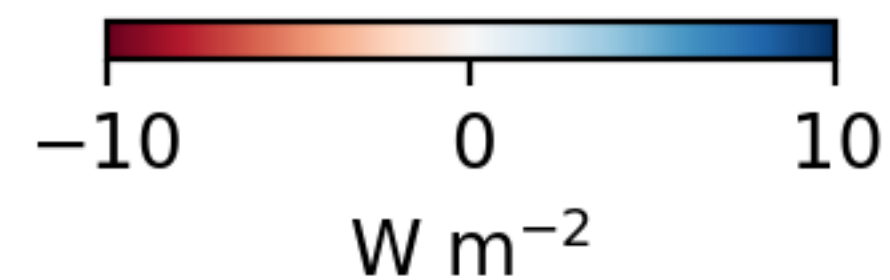
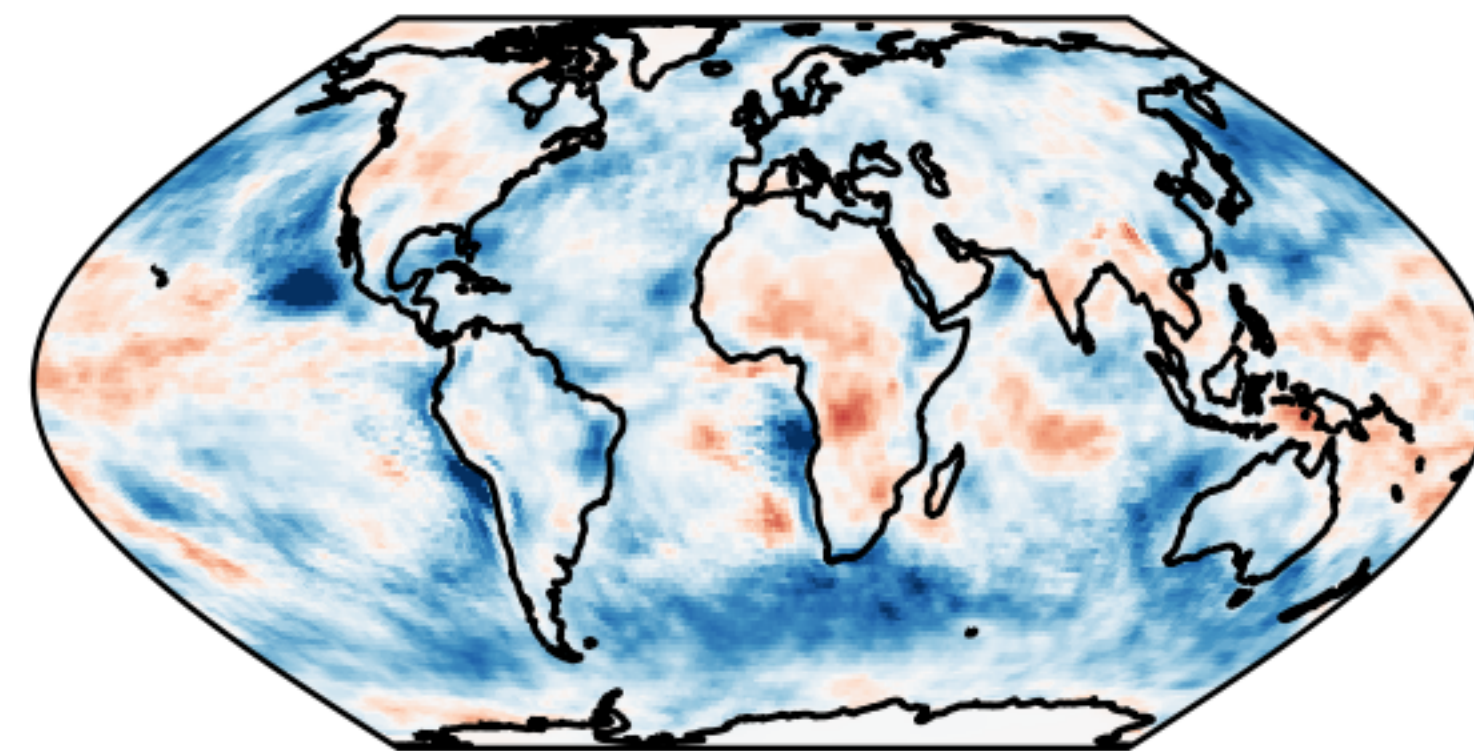
RRTMG, L93, SWCF (avg: -41.79)



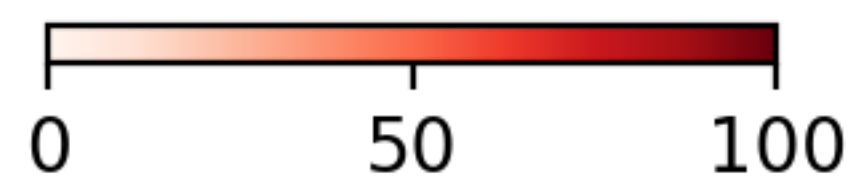
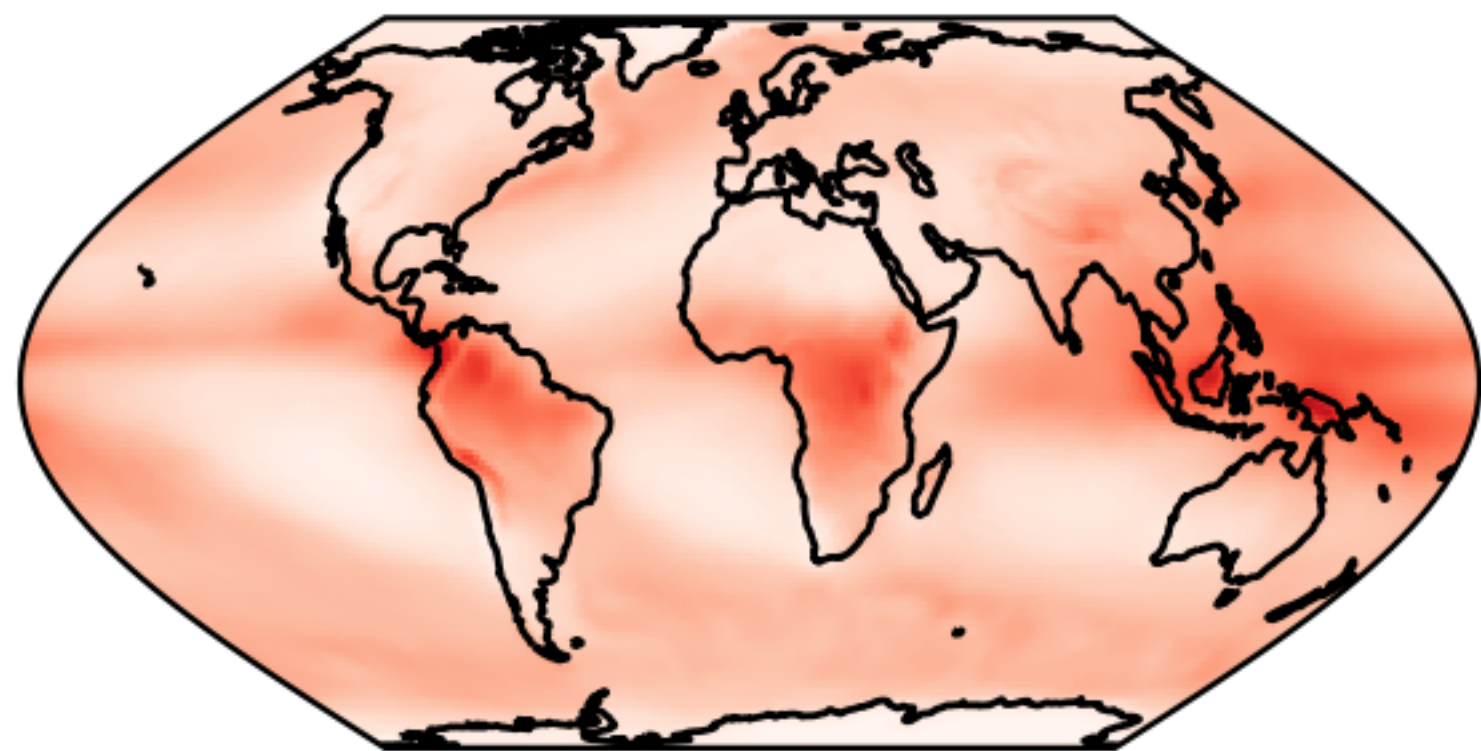
RRTMGP, L93, SWCF (avg: -40.16)



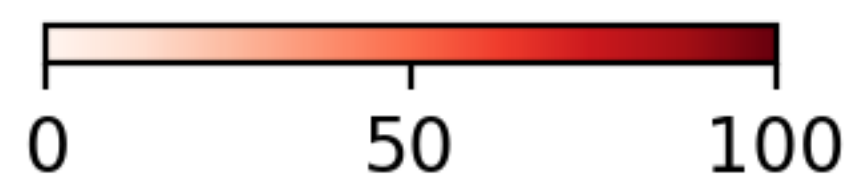
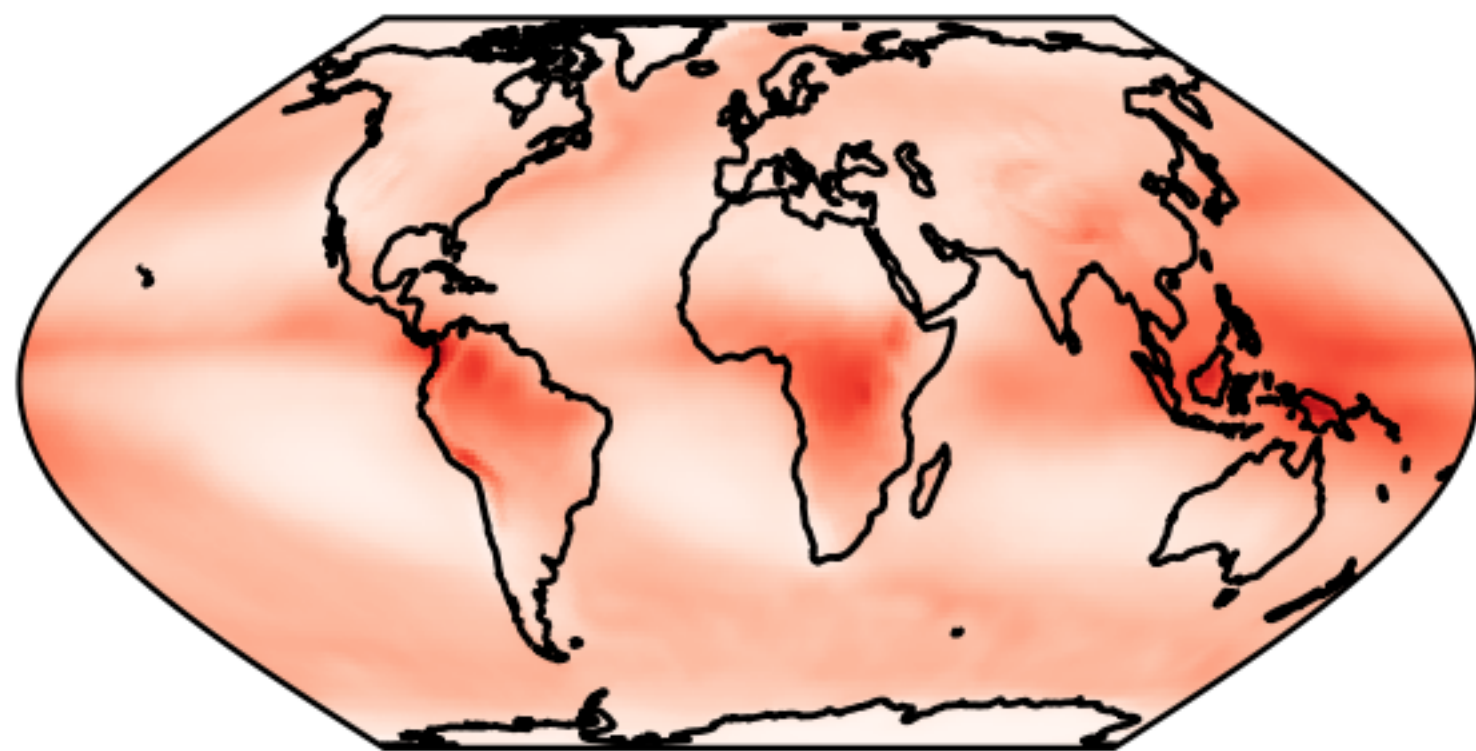
Difference (avg: 1.62)



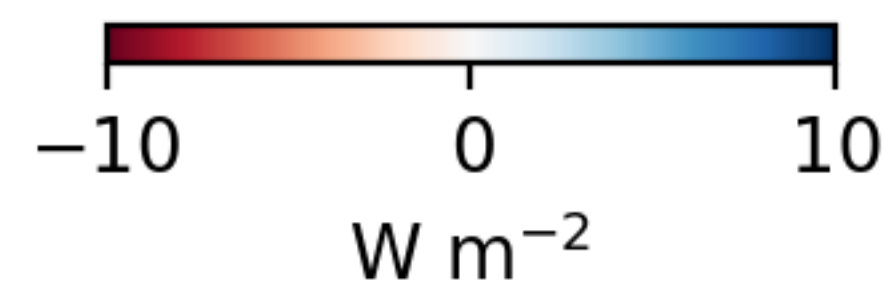
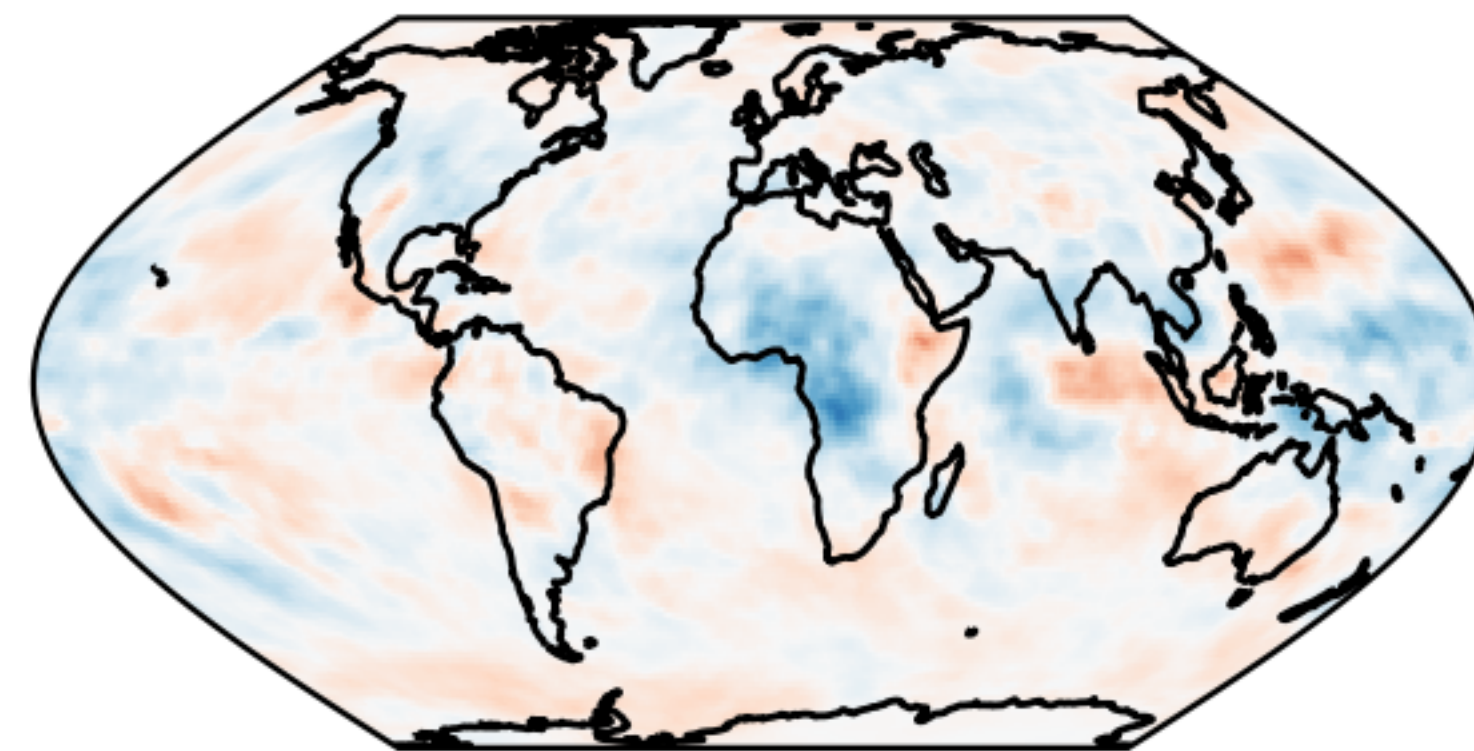
RRTMG, L93, LWCF (avg: 22.68)

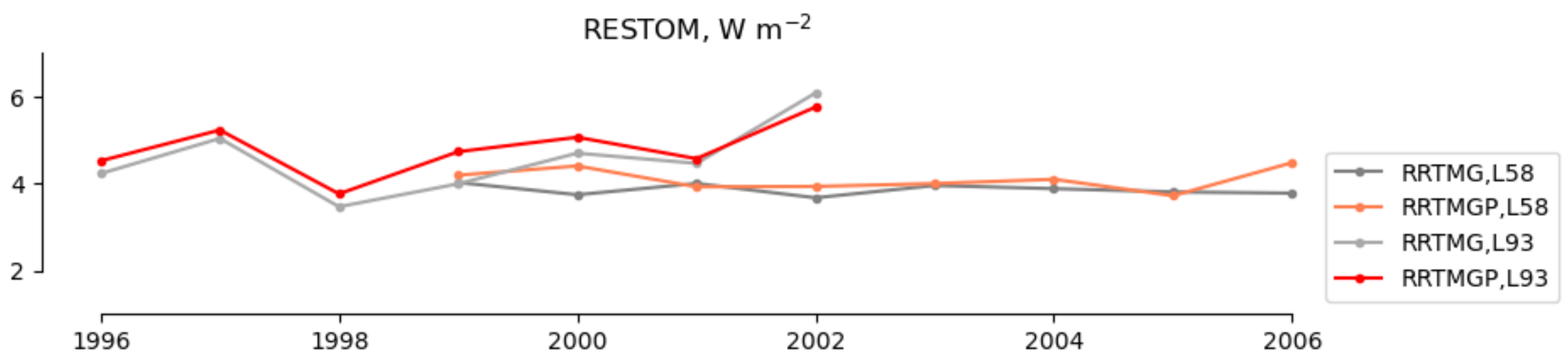


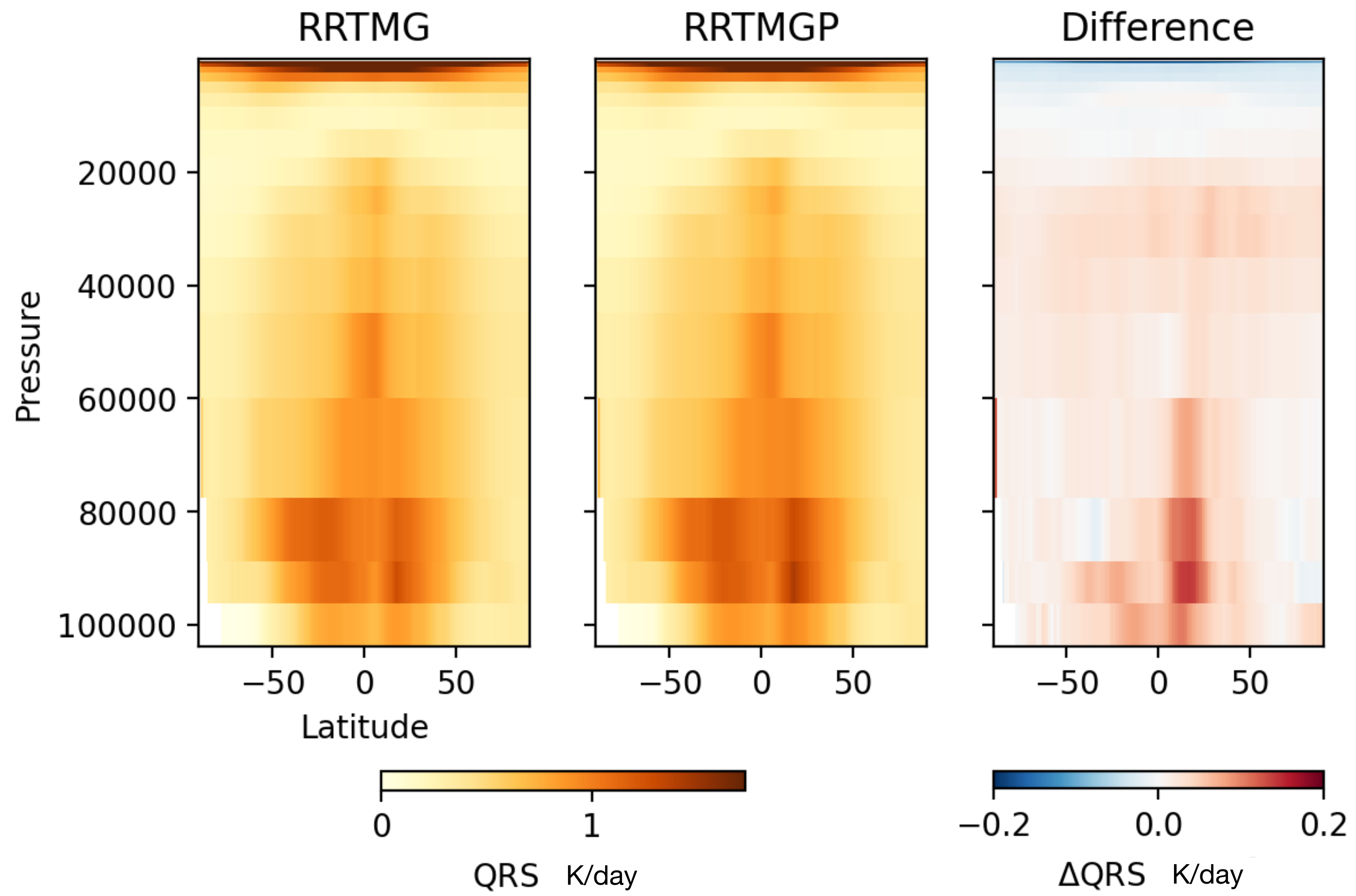
RRTMGP, L93, LWCF (avg: 22.84)

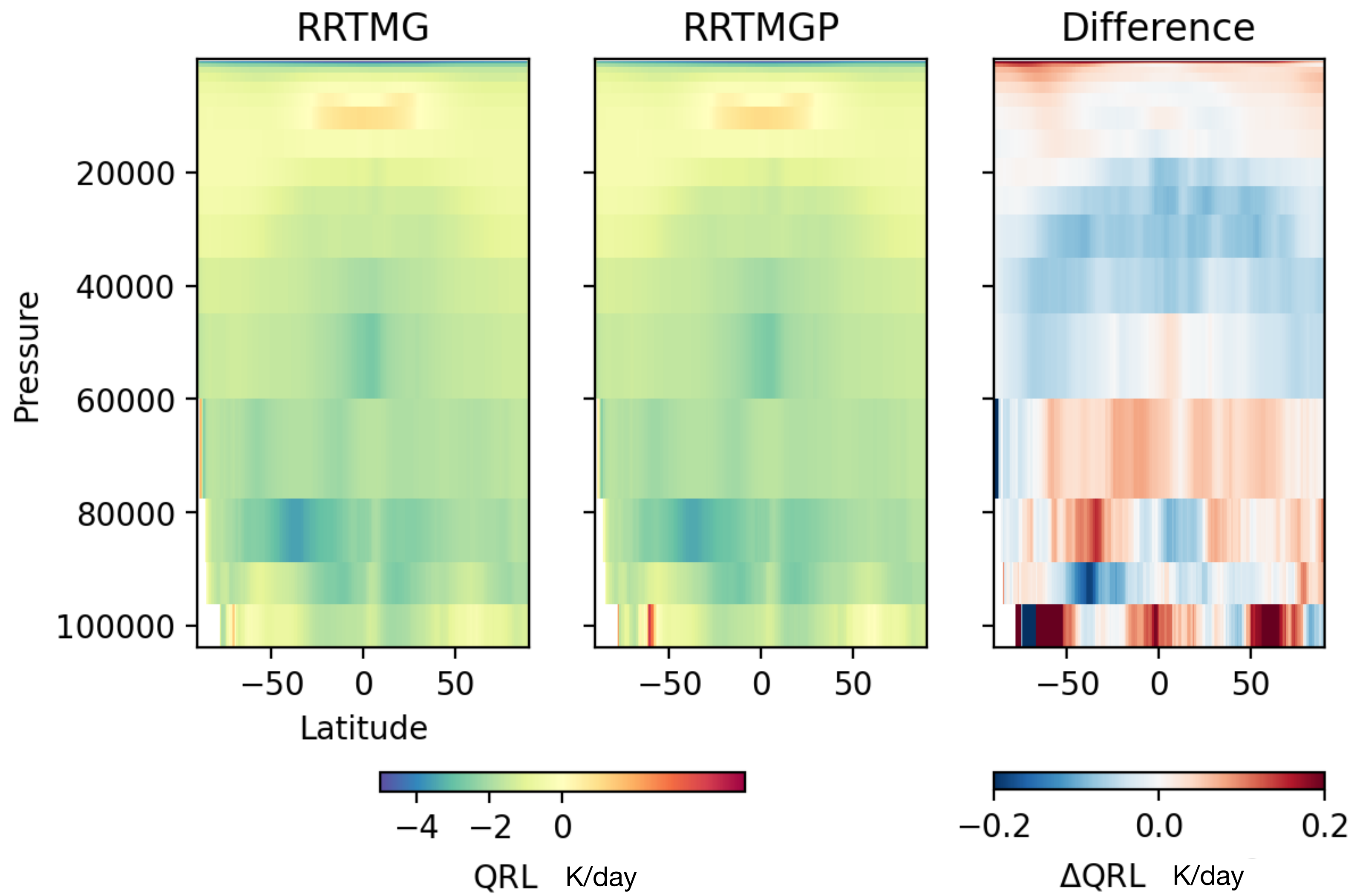


Difference (avg: 0.16)









Performance impact

derecho, 2160 pes, FLTHIST & FMTHIST

	RRTMG	RRTMGP
L58 2-year run	4232 pe-hrs/simulated_year	4263 pe-hrs/simulated_year
	12.2 simulated_years/day	12.3 simulated_years/day
	998s	1133s
L93 6-month run	8846 pe-hrs/simulated_year	9061 pe-hrs/simulated_year
	5.9 simulated_years/da	5.75 simulated_years/day
	392s	512s

- RRTMGP will be available as an option, at least
- In default configuration, there is a slight performance penalty
- Results with F*THIST compsets showing fairly modest differences,
 - but changing to RRTMGP looks like it will require some tuning
- RRTMGP already works on GPU, and CISL/EarthWorks are working to optimize it
- There is a version of RRTMGP that is CCPP-ized (probably not drop-in replacement, but something to start from)
- There are efforts to optimize the calculations within RRTMGP, including using machine learning to replace the lookup tables and interpolation. Examples:
 - Ukkonen & Hogan, 2023
 - Veerman et al., 2021
- The spectroscopy used in RRTMGP is updated, so even without other features, the clear-sky radiative transfer are more accurate (Pincus et al. 2019)