The SEA-ESF Radiation Code -- Lima release

Richard Hemler
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This document contains information about the sea-esf radiation code as implemented in the Lima release of the FMS. It is intended to provide an overview of the radiation code organization, rather than to address any science issues. Documentation for each of the component modules is included in the .f90 file containing that module which may be used to generate a .html file containing specific information related to that module. As is always the case, it is intended that additional enhanced documentation for the individual modules and for the package as a whole will be released at a later date.

The following sections are contained in this document:

A. An overview of the features of the sea lw code and the esf sw code.
B. A summary of the major changes made since the Jakarta release.
C. The organizational structure of the sea-esf radiation code.
D. Chart indicating the relationship between the modules active in AM2.
E. Summary of namelist variables and acceptable values for them.

A. Character of the sea lw radiation code and the esf sw radiation code

Among the features and capabilities within the sea-esf radiation code are :

1. ESF Shortwave code
   a.) The exponential-sum-fit sw code uses either 25 bands and 72 frequency points (high resolution) or 18 bands and 38 frequency points (low resolution, default for the AM2 model) to define the solar spectrum, allowing the proper interaction of various atmospheric

components with the spectrum. The scheme optionally includes the effects of aerosols on the solar heating rates and fluxes.

b.) Cloud radiative properties are defined based on cloud micro-physical properties.

2. SEA Longwave code
   a.) The ability to include the effects of the following radiatively-active gases on the LW fluxes and heating rates is present, in addition to CO_2, H_2O and O_3 : CH_4, N_2O, and 4 CFCs : f11, f12, f22, and f113.
   b.) The effects of water vapor continuum absorption may be calculated using either the CKD 2.1 or CKD 2.4 versions of the AFGL continuum absorption algorithm or the Roberts continuum.
   c.) A 16 lw band structure is used .
   d.) Aerosol effects on the LW fluxes and heating rates are included.
   e.) Cloud radiative properties are defined based on cloud micro-physical properties.
   f.) Longwave transmission functions for the well-mixed greenhouse gases (CO_2, CH_4, N_2O) at model species amount, temperatures and pressures are computed (online) from transmission functions for these gases at standard species amounts, temperatures and at 496 standard pressure levels.

3. Standalone driver - There is a standalone driver available to run the radiation code in either of three modes : in a program designed to assess radiative feedbacks using GCM-generated input, in a standalone column mode used to assess various aspects of the parameterization and assist in its further development, or using GCM-generated input to calculate instantaneous radiative forcings.

B. Summary of changes between Khartoum and Lima

The following new capabilities were added to the khartoum code version:

1. The following new features are now available when running the radiation code in standalone mode:
   a) the ability to process input fields from a foreign vertical grid;
   b) the ability to use physics windows;

c) the increased use of specified netcdf attributes in reading input files;
d) ability to process separate input files for atmospheric and cloud input fields, which may contain different numbers of data columns and/or time slices;
e) ability to transpose time dimension to the y dimension to allow domain decomposition and parallel execution when time marching is not present;
f) provides ability to run the fixed-dynamical-heating application with the standalone code;
g) adds two new input_data_sources (single_column and monthly_ts) to allow additional applications;
h) restructures the vertical grid specification of the input data set to provide additional generality.

2. The ability to specify via nml or input file time-and space-invariant astronomical parameters (zenith angle, fracday, earth-sun distance) is added.
3. The ability to specify ozone and aerosol profiles to be the same in all columns by extracting a nml-specified column from the respective climatology files, or by reading an input file (native or netcdf) has been added.
4. The ability to output direct and diffuse downward clearsky sw sfc flux diagnostics has been added.
5. The treatment of ch4 and n2o has been completely separated. Previous code versions used a compound control variable do_ch4_n2o, which is now replaced by two variables do_ch4 and do_n2o. This provides a) independent treatment of these two gases with respect to their presence or absence; b) the ability to specify either a single or multiple lw bands in the 1200 - 1400 cm(-1) region, independent of the presence or absence of these two gases; and c) the ability to use temperature dependent h2o emission lines in the 1200 - 1400 band independent of the presence or absence of these gases. Values of ch4 and/or n2o mixing ratio may now be specified as 0.0 without causing code problems; thus the option of specifying ‘absent’ for xxx_data_source has been eliminated.
6. The ability to generate diagnostics for total column aerosol (std + volcanic) extinction and absorption optical depths for nml-specified aerosol families in the visible and nir sw bands and in the 900-990 and 990-1070 lw bands has been added.

7. A check was added to prevent specifyingg diurnally varying solar radiation using an averaging period of exactly one day. The averaging period must be no greater than 12 hours; the special case of 1 day had slipped through the logic previously.
8. Any reference to ice particle radius is removed. Size is specified in terms of effective size.
9. The ability to specify a latitude and longitude to be used for the astronomical calculations that does not vary with grid point was added. Thus the toa solar input will be uniform for all grid columns.
10. The time-averaged surface albedo diagnostic is redefined in terms of the ratio of accumulated upward sw flux to accumulated downward sw flux. The previous diagnostic was flawed in that arbitrary values assigned during periods of darkness were included in the time-averaged diagnostic, so that truly meaningful values could only be obtained during post-processing.
11. The ability to run the radiation package without the effects of ozone and/or water vapor has been added.
12. Mods to interpolator_mod were made to eliminate the printout of excessive NOTES and to allow fixed-year data from the climatology files to be used during standalone radiation jobs which are run for greater than one year.

C. Organization of the radiation package

0. Radiation package utility modules

Three modules are contained within the radiation package to contain general information that is accessed by many of the modules. These are:

atmos_param/sea_esf_rad/rad_utilities.f90 - Rad_utilities_mod contains the various derived-type variables used within the radiation package to communicate betwen modules. It also contains basic information and routines to perform basic functions, such as table access and band-averaging.

atmos_param/sea_esf_rad/esfsw_parameters.f90 : Esfsw_parameters_mod contains the parameter settings for the esf99 sw package.

atmos_param/sea-esf_rad/longwave_params/f90 : Longwave_params_mod contains parameters used in the sea99 lw package.

1. Level 1 modules (accessed by physics_driver_mod)

The radiation code is connected to the outside through physics_driver_mod (when run in GCM mode), or to a driver program when run in standalone mode. As described in atmos_param/physics_driver/Radiation_overview.ps, inputs to radiation are required to come in through the argument list. As a consequence, modules have been provided to be accessed by physics_driver (or the standalone main program) to obtain these inputs, in anticipation of the day when aerosols and radiative gases may become prognostic, just as clouds optionally may be currently. These modules are:

to obtain the radiative gas fields:
atmos_param/sea_esf_rad/radiative_gases.f90
to obtain the cloud and microphysics fields:
atmos_param/sea_esf_rad/cloud_spec.f90
to obtain the aerosol fields:
atmos_param/sea_esf_rad/aerosol.F90

Physics_driver_mod accesses these modules in addition to radiation_driver_mod.

2. Level 2 modules (accessed by Level 1 modules)

a) Radiative_gases_mod accesses the following module:

to obtain ozone data :
atmos_param/sea_esf_rad/ozone.f90

The remaining radiative gases are treated within radiative_gases_mod since they are currently assumed spatially uniform. If their specification / treatment becomes more complicated, separate modules will be created for them, as exists curcurrently with ozone.

b) Cloud_spec_mod accesses one of the following wrapper mods, dependent on the cloud parameterization which has been activated, in order to obtain the cloud specification information which will be passed on to radiation_driver_mod:

to access the strat_cloud module:

atmos_param/sea_esf_rad/strat_clouds_W.f90

to access the Gordon diagnostic clouds module:

atmos_param/sea_esf_rad/diag_clouds_W.f90

to access either a zonally-prescribed cloud module or the observed cloud module:

atmos_param/sea_esf_rad/specified_clouds_W.f90

to access a cloud scheme diagnosing clouds based on model relative humidity:

atmos_param/sea_esf_rad/rh_based_clouds.f90

to access the clouds produced by the donner_deep module:

atmos_param/sea_esf_rad/donner_deep_clouds_W.f90

to access an alternative zonally prescribed cloud scheme:

atmos_param/sea_esf_rad/mgrp_pscr_clds.f90

to access the module providing clouds for use with the standalone column program:

atmos_param/sea_esf_rad/standalone_clouds.f90

to access the module providing clouds for use with the ZETAC model:

atmos_param/sea_esf_rad/zetac_clouds_W.f90

c) Aerosol_mod accesses no lower-level modules within the radiation package. It currently obtains aerosol data by interpolation into a supplied aerosol climatology, using an interpolation module contained within the FMS atmos_shared directory.

d) Radiation_driver_mod is called by physics_driver_mod (or standalone main program) and then accesses the following modules:

to access the original fms radiation code (legacy code):

atmos_param/sea_esf_rad/original_fms_rad.f90

to access the sea_esf_rad radiation package:

atmos_param/sea_esf_rad/sea_esf_rad.f90

to output radiation package diagnostics in a netcdf file:

atmos_param/.sea_esf_rad/rad_output_file.f90

to obtain cloud radiative properties to be passed on to the longwave and shortwave codes:

atmos_param/sea_esf_rad/cloudrad_package.f90

to obtain aerosol radiative properties to be passed on to the longwave and shortwave codes:

atmos_param/sea_esf_rad/aerosolrad_package.f90

Radiation_driver_mod also uses two support modules not contained in the radiation package directory:

to obtain the astronomical parameters needed by the sw radiation package:
atmos_param/astronomy/astronomy.f90

to process diagnostic global and/or hemispheric integrals:
atmos_param/diag_integral/diag_integral.f90

3. Level 3 modules (accessed by Level 2 modules)

Ozone_mod does not access any lower-level radiation routines.

The various wrapper routines accessed by cloud_spec_mod will talk to the associated cloud parameterization modules, if they exist, in order to obtain the cloud data which will ultimately be passed to the radiation package. (The simpler schemes may not have a specific parameterization module). There is not a lower level set of sea_esf_rad modules which are accessed.

Sea_esf_rad_mod accesses the following modules:

to obtain longwave heating rates and fluxes:
atmos_param/sea_esf_rad/longwave_driver.f90

to obtain shortwave heating rates and fluxes:
atmos_param/sea_esf_rad/shortwave_driver.f90

to obtain radiation column diagnostics :
atmos_param/sea_esf_rad/radiation_diag.f90

Rad_output_file_mod does not access any lower-level radiation modules.

Cloudrad_package_mod accesses the following modules:

to obtain microphysically-based cloud radiative properties, when needed:
atmos_param/sea_esf_rad/microphys_rad.f90

to obtain bulk-physics based cloud radiative properties, when needed:

atmos_param/sea_esf_rad/bulkphys_rad.f90

to produce netcdf diagnostics related to the clouds and cloud radiative properties seen by the radiation package:

atmos_param/sea_esf_rad/cloudrad_diagnostics.f90

Aerosolrad_package_mod does not access lower-level radiation routines.

4. Level 4 modules (accessed by Level 3 modules)

Longwave_driver_mod accesses the internal driver for the longwave radiation parameterizations available in the sea-esf radiation package. Currently only one package is available, sealw99. It is accessed at

atmos_param/sea_esf_rad/sealw99.f90

Shortwave_driver_mod accesses the available shortwave parameterizations;

to access the Lacis-Hansen shortwave parameterization:

atmos_param/sea_esf_rad/lhsw_driver.f90

to access the esf99 shortwave parameterization:

atmos_param/sea_esf_rad/esfsw99.f90

Radiation_diag_mod does not access any lower-level modules.

Microphys_rad_mod does not access any lower-level modules.

Bulkphys_rad_mod accesses the cloud parameterization wrapper modules as described under Level 1 module cloud_spec_mod.

Cloudrad_diagnostics_mod accesses the radiative properties module associated with the strat_cloud parameterization and a diagnostic module used to relate the model clouds to the ISCCP cloud types:

atmos_param/sea_esf_rad/isccp_clouds.f90

5. Level 5 modules (accessed by Level 4 modules)

Sealw99_mod is the internal driver for the sea99 lw radiation package. The component modules making up this package are:

atmos_param/sea_esf_rad/longwave_clouds.f90
atmos_param/sea_esf_rad/longwave_fluxes.f90
atmos_param/sea_esf_rad/longwave_tables.f90
atmos_param/sea_esf_rad/optical_path.f90
atmos_param/sea_esf_rad/gas_tf.f90
atmos_param/sea_esf_rad/lw_gases_stdtf.f90

Esfsw99_mod is the internal driver for the esf99 sw package. It has no component modules.

Lhsw_driver_mod is the internal driver for the Lacis-Hansen sw package. It has no component modules.

Isccp_clouds_mod uses no lower-level radiation package modules.

C. AM2 module relationship chart

Following is a summary of the relationship between the radiation package modules for those modules active in the AM2 GCM.

physics_driver --> aerosol

physics_driver --> radiative_gases --> ozone

physics_driver --> cloud_spec --> strat_clouds_W

physics_driver --> radiation_driver --> rad_output_file
physics_driver --> radiation_driver --> aerosolrad_package
physics_driver --> radiation_driver --> astronomy
physics_driver --> radiation_driver --> diag_integral

physics_driver --> radiation_driver --> cloudrad_package --> microphys_rad
physics_driver --> radiation_driver --> cloudrad_package -->
cloudrad_diagnostics --> isccp_clouds

physics_driver --> radiation_driver --> sea_esf_rad -->
longwave_driver--> sealw99 -->
gas_tf, lw_gases_stdtf, optical_path,
longwave_clouds, longwave_fluxes,
longwave_tables
physics_driver --> radiation_driver --> sea_esf_rad -->
shortwave_driver--> esfsw99
physics_driver --> radiation_driver --> sea_esf_rad -->
radiation_diag

The rad_utilities, esfsw_parameters and longwave_params modules may be accessed by any of the above modules.

D. Namelist variables within the sea_esf_rad modules

In the following table, variables in **bold type** denoted with (**) require the user to replace the default value with a realistic one when running the model **regardless of what execution options are chosen**. Other variables exist which must be set to realistic values when the relevant option is chosen; these are also in **bold type**, but denoted by (*). The values of any variable may be changed as the user wishes; it is intended that internal checks will prevent the use of inconsistent options.

Table 1: Namelist variables used with the sea-esf radiation package

Module	Variable Name	Description	Default Value	Other Acceptable Values
aerosol	***data_names**	names of active aerosol species	‘ ‘	names contained in aerosol input file
	***filename**	name of netcdf file containing aerosol data	‘ ‘	

Table 1: Namelist variables used with the sea-esf radiation package

Module	Variable Name	Description	Default Value	Other Acceptable Values
	family_names	names given to aerosol families	‘ ‘	
	use_aerosol_time_series	use a timeseries providing interannual aerosol variation ?	.false.	
	aerosol_dataset_entry	time in aerosol timeseries that is mapped to model initial time	1,1,1,1,1,1	
	in_family[1,2,3,...9]	aerosol species n is in family number [1,2,3, ...9] ?	.false.	
	aerosol_data_source	source of aerosol data	’climatology’	’calculate_column’, ‘input’,
	lonb_col	longitudes defining the region to use for column data calculation	(/-999, -999/)	
	latb_col	latitudes defining the region to use for column data calculation	(/-999, -999)/	
	time_col	time to use for column data calculation	(/ 0,0,0,0,0,0/)	
	volc_in_fam_col_opt_depth[1,2,3,...9]	is the volcanic contribution to column optical depth to be included for this family in the netcdf output fields ?	.false.	
aerosolrad_package	do_lwaerosol	aerosol effects included in lw radiation ?	.false.	
	do_swaerosol	aerosol effects included in sw radiation ?	.false.	
	***aerosol_data_set**	source of aerosol data	‘ ‘	‘shettle-fenn’, ‘predicted

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Module	Variable Name	Description	Default Value	Other Acceptable Values
	***aerosol_optical_names**	names associated with active aerosol optical property types	‘ ‘	see module for available set, names contained in optical_filename
	***optical filename**	name of file containing optical property types	‘ ‘	
	using_volcanic_lw_files	volcanic aerosol optical properties are supplied to the lw radiation code?	.false.	
	using_volcanic_sw_files	volcanic aerosol optical properties are supplied to the sw radiation code ?	.false.	
	***[sw_ext, sw_ssa, sw_asy, lw_ext, lw_ssa, lw_asy]_filename**	name of file in which the specified volcanic aerosol optical properties are to be found	‘ ‘	
	***[sw_ext, sw_ssa, sw_asy, lw_ext, lw_ssa, lw_asy]_root**	root variable name of the field in each file	‘ ‘	
	volcanic_dataset_entry	time in volcanic data time series that is to be mapped to the model initial time	1,1,1,0,0,0	
	interpolating_volcanic_data	volcanic data is to be interpolated (rather than using the monthly values for the entire month and changing as the month changes) ?	.true.	
astronomy	ecc	orbital eccentricity	0.01671	
	obliq	obliquity	23.439	
	per	longitude of perihelion	102.932	
	period	length of year	0	see module

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Module	Variable Name	Description	Default Value	Other Acceptable Values
	day_ae	day of specified autumnal equinox	23	
	month_ae	month of specified autumnal equinox	9	
	year_ae	year of specified autumnal equinox	1998	
	hour_ae	hour of specified autumnal equinox	5	
	minute_ae	minute of specified autumnal equinox	37	
	second_ae	second of specified autumnal equinox	0	
	num_angles	number of intervals in yr used to calculate orbital positions	3600	
bulkphys_rad	dummy	dummy variable	1	
cloudrad_diagnostics	do_isccp	the isccp simulator code is to be executed ?	.false.	
	isccp_actual_radprops	use GCM provided radiative properties ?	.true.	
	isccp_scale_factor	accounts for the plane-parallel homogenous cloud bias	0.85	
cloudrad_package	****microphys_form**	type of microphysics to use when defining cloud radiative properties	‘ ‘	‘none’, ‘prescribed’, ‘predicted’

Table 1: Namelist variables used with the sea-esf radiation package

Module	Variable Name	Description	Default Value	Other Acceptable Values
cloud_spec	****cloud_type_form**	cloud parameterization name	‘ ‘	‘strat’, ‘rh’, ‘deep’, ‘strat-deep’,’zonal’, ‘obs’, ‘pre-scribed’, ‘diag’, ‘none’, ‘specified’, ‘not_sea_esf’
	wtr_cld_reff	cloud drop effective radius	10 microns	
	ice_cld_reff	ice cloud particle effective size	50 microns	
	rain_reff	rain drop effective radius	250 microns	
	overlap_type	cloud overlap assumption	‘random’	‘max-random’
	doing_data_override	is the cloud input data to the radiation package to be replaced by that obtained from another file ?	.false.	
diag_clouds_W	num_slingo_bands	number of wavelength bands used in the slingo parameterization	4	
	taucrit	critical optical depth at which solar beam becomes diffuse	1.0	
diag_integral	file_name	name of file to which integrals are written	‘ ‘	
	****output_interval**	interval at which to output integrals	-1	

Table 1: Namelist variables used with the sea-esf radiation package

Module	Variable Name	Description	Default Value	Other Acceptable Values
	time_units	units of output_interval	'hours'	'days', 'seconds', 'minutes'
	print_header	print a header for the integrals file ?	.true.	
	fields_per_print_line	number of fields per line of output	4	
donner_deep_clouds_W	using_dge_swe	use Fu(1998) scheme for ice sw optical depth ?	.true.	
	using_dge_lw	use Fu(1998) scheme for ice lw optical depth ?	.true.	
esfsw_driver	do_rayleigh_all_bands	rayleigh scattering is applied to all sw bands ?	.true.	
	do_ica_calcs	compute independent column values for sw fluxes (stochastic cloud option)	.false.	
	do_herzberg	add the herzberg sw effect ?	.false.	
	do_quench	add the sw quenching factor ?	.false.	
esfsw_parameters	****sw_resolution**	will allow ability to use either high or low resolution spectral parameterization	' '	'high', 'low'
	****sw_diff_streams**	number of streams of diffuse radiation	0	select either 1 or 4
gas_tf	interp_form	the form of table interpolation to be used when calculating the transmission functions	'log'	'linear'
	do_calcstdch4tfs	calculate the ch4 tfs	.true.	
	do_writestdch4tfs	write the ch4 tfs to a file to save	.false.	

Table 1: Namelist variables used with the sea-esf radiation package

Module	Variable Name	Description	Default Value	Other Acceptable Values
	do_readstdch4tfs	read the ch4 tfs from a file	.false.	
	do _calcstdn2otfs	calculate the n2o tfs	.true.	
	do_writestdn2otfs	write the n2o tfs to a file	.false.	
	do_readstdn2otfs	read the n2o tfs from a file	.false.	
	do_calcstdco2tfs	calculate the co2 tfs	.true.	
	do_writestdco2tfs	write the co2 tfs to a file	.false.	
	do_readstdco2tfs	read the tfs from a file	.false.	
isccp_clouds	ncol	number of columns used in ISCCP	50	
	top_height	how to handle cloud top height in isccp analysis	1	2, 3 -- see module for explanation
	isccp_taumin	minimum optical depth seen by ISCCP	0.3	
	emsfclw	assumed constant fraction of surface lw emissivity	0.94	
	do_sunlit_only	diagnostics done during sunlit hours only ?	.false.	
	overlap	overlap assumption used in isccp_cloud module	2 (random overlap)	1 = maxi-mum, 3= maximum-random
	minColsInhomo	minimum number of cloudy subcolumns needed to do inhomogeneous cal-culation	3	
lhsw_driver	dummy	dummy variable	0.0	
	nbands_to_use	number of sw bands	9	12
	calculate_o2_absorpti on	O2 absorption effects should be included ?	.false.	

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Module	Variable Name	Description	Default Value	Other Acceptable Values
longwave_clouds	dummy	dummy variable	.false.	
longwave_driver	lwform	character string describing lw parameterization being used	'sealw99'	
longwave_fluxes	dummy	dummy variable	1.0	
longwave_params	dummy	dummy variable	' '	
longwave_tables	dummy	dummy variable	1.0	
lw_gases_stdtf	do_coeintdiag	include diagnostic print-out of some coefficients ?	.false.	
	nstdco2lvls	number of levels contained in the tabulated lbl tfs	496	previously was 109.
mgrp_prscr_clds	dummy	dummy variable	0	
microphys_cloud	diam_liq	diameter of liquid droplets	33.2 microns	
microphys_rad	***lwem_form**	lw emissivity parameter-ization type	' '	'fuliou', 'ebertcurry'
optical_path	dummy	dummy variable	0.0	
original_fms_rad	lat_diag	latitude for diagnostics column (degrees)	-1000.	-90. -> 90.
	long_diag	longitude for diagnostics column (degrees)	-1000.	0. -> 360.
	solar_constant	solar constant (W/m**2)	1365.	
	co2std	co2 mixing ratio	330.	300.
	ratio	factor to multiply co2std by to get co2 value being used	1.0	0.5 - 4.0
ozone	basic_ozone_type	label for ozone type	'clim_zonal'	'time_varying', 'fixed_year'

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Module	Variable Name	Description	Default Value	Other Acceptable Values
	ozone_data_source	source for ozone data	'fortuin_kel der'	'input', 'gfdl_zonal _ozone', mozart_moz top_fk, mozart_trop _fk,calculat e_column
	clim_base_year	year with which the ozone data set is associated	'1990'	'1979', '1997', '1850', 1860'
	trans_data_type	time_interpolation method to use	'linear'	
	gfdl_zonal_ozone_typ e	time flavor of ozone data set to be used	'seasonally-varying'	'winter', 'spring', 'summer', 'autumn', 'annual_me an'
	do_mcm_o3_clim	treat ozone as in manabe climate model ?	.false.	
	filename	name of file containing ozone data	'o3.trend.nc '	
	data_name	name of variable in file to be accessed	'ozone_199 0'	
	ozone_dataset_entry	time in ozone timeseries which is mapped to model initial time	1,1,1,0,0,0	
	lonb_col	longitudes defining the region to use for column data calculation	(/-999., -999./)	
	latb_col	latitudes defining the region to use for column data calculation	(/-999., -999./)	

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Module	Variable Name	Description	Default Value	Other Acceptable Values
	time_col	time to use for column calculation	(/ 0,0,0,0,0,0/)	
rad_output_file	write_data_file	radiation output data file to be written ?	.false.	
rad_utilities	dummy		0	
radiation_diag	***iradprt_gl**	global i indices of points at which radiation diagnostics are to be generated	0	
	***jradprt_gl**	global j indices of points at which radiation diagnostics are to be generated	0	
	num_pts_ij	number of points specified by global indices at which to generate radiation diagnostics	0	
	num_pts_latlon	number of points specified by lat-lon at which to generate radiation diagnostics	0	
	***latradprt**	latitudes of points at which diagnostics are desired	999.	
	***lonradprt**	longitudes of points at which diagnostics are desired	999.	
radiation_driver	****rad_time_step**	radiation time step in seconds	0	
	do_clear_sky_pass	are clear-sky radiation diagnostics to be calculated?	.false.	
	****zenith_spec**	string defining how zenith angle is computed	‘ ‘	‘daily_mean’, ‘annual_mean’, ‘diurnally-varying’

Table 1: Namelist variables used with the sea-esf radiation package

Module	Variable Name	Description	Default Value	Other Acceptable Values
	rad_package	string defining radiation package being used	‘sea_esf’	‘original_f ms’
	calc_hemi_integrals	are hemispheric integrals desired ?	.false.	
	do_netcdf_restart	netcdf vs. native restart	.true.	
	all_step_diagnostics	are lw and sw radiative bdy fluxes and atmo- spheric heatingrates to be output on physics steps ?	.false.	
	renormalize_sw_fluxe s	should sw fluxes be renor- malized on each step to account for earth-sun movement between radia- tion steps ?	.false.	
	rad_date	use the input fields at this time rather than the current model time to calculate the radiative forcings	(0,0,0,0,0,0)	
	all_level_radiation	radiation is to be calcu- lated at all model levels ?	.true.	
	***topmost_radiation_ level**	highest model level at which radiation is calcu- lated; only needed when all_level_radiation is .false.	-99	
	drop_upper_levels	if all_level_radiation is .false. and drop_upper_levels is .true., radiation will only be cal- culated from topmost_radiation_level to the surface	.false.	
	all_column_radiation	radiation is to be calcu- lated in all model columns ?	.true.	

Table 1: Namelist variables used with the sea-esf radiation package

Module	Variable Name	Description	Default Value	Other Acceptable Values
	rsd	call radiation for same date (yr,day), but repeatedly run through the diurnal cycle	.false.	
	use_mixing_ratio	assume q is mixing ratio rather than specific humidity on input ?	.false.	
	solar_constant	annual mean solar flux toa	1365.0	
	trop_ht_at_poles	height of tropopause at poles (when linear_tropo is .true.)	300 hPa	
	trop_ht_at_eq	height of tropopause at equator (when linear_tropo is .true.)	100 hPa	
	trop_ht_constant	heigt of tropopause when constant_tropo is .true.	200 hPa	
	constant_tropo	diagnostics calculated assuming height of tropopause is constant ?	.true.	
	linear_tropo	diagnostics calculated assuming ht of tropopause varies linearly from equator to pole ?	.true.	
	thermo_trop	diagnostics calculated assuming ht of tropopause is determined thermodynamically ?	.false.	
	time_varying_solar_constant	solar input at toa varies with time ?	.false.	
	solar_dataset_entry	time in solar timeseries which is mapped to model initial time	1,1,1,0,0,0	

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Module	Variable Name	Description	Default Value	Other Acceptable Values
	doing_data_override	input fields to the radia-tionpackage are being overriden using data_override_mod ?	.false.	
	overriding_temps	temperature and ts fields areoverriden ?	.false.	
	overriding_sphum	specific humidity field is overriden ?	.false.	
	overriding_albedo	surface albedo field is overriden ?	.false.	
	overriding_aerosol	aerosol fields are overriden ?	.false.	
	always_calculate	radiation calculation is done on every call to radiation_driver ?	.false.	
	do_h2o	h2o radiative effects aren-cluded in the radiationcal-culation ?	.true.	
	do_o3	o3 radiative effects arein-cluded in the radiationcal-culation ?	.true.	
	use_uniform_solar_in put	! the (lat,lon) values used to calculate zenith angle are uniform across the grid ?	.false.	
	lat_for_solar_input	latitude to be used when uniform solar input is acti-vated [degrees]	100.	
	lon_for_solar_input	longitude to be used when uni-orm solar input is acti-vated [degrees]	500.	

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Module	Variable Name	Description	Default Value	Other Acceptable Values
radiative_gases	****ch4_data_source**	source of ch4 data to be used	‘ ‘	‘restart’, ‘icrccm’, ‘ipcc_92’, ‘ipcc_98’, ‘ipcc_80’, ‘input’, ’pre-scribed’, ‘predicted’, ‘namelist’,
	****n2o_data_source**	source of n2o data to be used	‘ ‘	‘restart’, ‘icrccm’, ‘ipcc_92’, ‘ipcc_98’, ‘ipcc_80’, ‘input’,’pre-scribed’, ‘predicted’, ‘namelist’
	****f11_data_source**	source of f11 data to be used	‘ ‘	‘restart’, ‘icrccm’, ‘ipcc_92’, ‘ipcc_98’, ‘ipcc_80’, ‘input’,’pre-scribed’, ‘predicted’, ‘namelist’
	****f12_data_source**	source of f12 data to be used	‘ ‘	‘restart’, ‘icrccm’, ‘ipcc_92’, ‘ipcc_98’, ‘ipcc_80’, ‘input’,’pre-scribed’, ‘predicted’, ‘namelist’

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Module	Variable Name	Description	Default Value	Other Acceptable Values
	****f113_data_source**	source of f113 data to be used	‘ ‘	‘restart’, ‘icrccm’, ‘ipcc_92’, ‘ipcc_98’, ‘ipcc_80’, ‘input’,’prescribed’, ‘predicted’, ‘namelist’
	****f22_data_source**	source of f22 data to be used	‘ ‘	‘restart’, ‘icrccm’, ‘ipcc_92’, ‘ipcc_98’, ‘ipcc_80’, ‘input’,’prescribed’, ‘predicted’, ‘namelist’
	****co2_data_source**	source of co2 data to be used	‘ ‘	‘restart’, ‘icrccm’, ‘ipcc_92’, ‘ipcc_98’, ‘ipcc_80’, ‘input’,’prescribed’, ‘predicted’, ‘namelist’, ‘330ppm’, ‘660ppm’
	time_varying_xxx	gas xxx varies with time ?	.false.	
	xxx_dataset_entry	time in xxx data set corresponding to modelinitial time (yr, mo, dy, hr, mn, sc)	(/ 1, 1, 1, 0, 0, 0 /)	

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Module	Variable Name	Description	Default Value	Other Acceptable Values
	xxx_base_value	base value to be used along with xxx-base_time and xxx_change_rate to determine gas concentration at a given time (when xxx_specification_type is 'base_and_trend')	0.0	
	xxx_base_time	base value to be used along with xxx-base_value and xxx_change_rate to determine gas concentration at a given time (when xxx_specification_type is 'base_and_trend')	0,0,0,0,0,0	
	xxx_change_rate	base value to be used along with xxx-base_time and xxx_base_value to determine gas concentration at a given time (when xxx_specification_type is 'base_and_trend')	0.0	
	xxx_floor	lowest acceptable value for gas xxx vol mixing ratio	0.0	
	xxx_ceiling	highest acceptable value for gas xxx vol mixing ratio	1.0E6	
	xxx_specification_type	indicator as to form of time variation of gas xxx (needed when gas is time-varying)	' '	'time_series', 'base_and_trend'
	xxx_variation_type	form of time variation of gas xxx (needed when gas is time-varying)	' '	'linear', 'logarithmic'
	verbose	control over printed output	0 (least)	0 - 5

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Module	Variable Name	Description	Default Value	Other Acceptable Values
	gas_printout_freq	frequency at which gas mixing ratios are output to stdout (hours)	32 days	
rh_based_clouds	cirrus_cld_prop_form	the ‘blackness’ of cirrus clouds	‘full’	‘part’ ‘
sea_esf_rad	dummy	dummy variable	.false.	
sealw99	do_nlte	is a region of non-local thermodynamic equilibrium included in the model ?	.false.	
	do_thick	an optional parameterization of the longwave flux in thick clouds is used ?	.false.	
	do_lwcldemiss	a cloud emissivity that varies with frequency band is used in the lw calculation ?	.false.	
	do_ch4lbltmpint	development option	.false.	
	do_n2olbltmpint	development option	.false.	
	****continuum_form**	continuum specification	‘ ‘	‘ckd2.1’, ‘ckd2.4’, mt_ckd1.0’, ‘rsb’, ‘none’
	****linecatalog_form**	line catalog specification	‘ ‘	‘hitran_1992’, ‘hitran_2000’
	verbose	control over printed output	0 (least)	0 - 5
	calc_xxx_tfs_month;ly	calculate the tfs for gas xxx once a month ?	.false.	
	calc_xxx_tfs_on_first_step	calculate tfs for gas xxx on the first step of job ?	.true.	
	use_current_xxx_for_tf	use gas value at current time when calculating tfs ?	.false.	

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Module	Variable Name	Description	Default Value	Other Acceptable Values
	xxx_tf_time_displacement	time displacement of gas value to be used in tf calculation	0.0	
	xxx_tf_calc_intrvl	interval between calculating gas tfs [hours]	1.0E6	
shortwave_driver	****swform**	shortwave parameterization to be used	‘ ’	‘lhsw’, ‘esfsw99’
	do_cmip_diagnostics	execute code needed to obtain cmip aerosol diagnostics ?	.false.	
	calculate_volcanic_sw_heating	make an extra call to esfsw_driver so that volcanic sw heating may be diagnosed ?	.false.	
specified_clouds_W	dummy	dummy variable	0	
standalone_clouds	***cldht_type_form**	formulation used to define the boundaries between low, middle and high clouds	‘ ‘	‘60’, ‘93’, ‘skyhi’
	***cloud_data_form**	source of cloud data ilocation and amount, either an input file or as specified in code	‘ ‘	‘input’, ‘specified’
	***cloud_data_points**	number of columns of data being supplied to standalone code	0	must be >= 1 to run
	***cloud_overlap_form**	are we using random overlap assumption or maximum-random overlap assumption ?	‘ ‘	‘random’, ‘max_random’
	***lhsw_cld_prop_form**	define cvisrf, cirrf and cirab from input file or as specified within code	‘ ‘	‘input’, ‘specified’

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Module	Variable Name	Description	Default Value	Other Acceptable Values
	***lw_cld_prop_form**	define lw emissivity from either input file or as specified in code	‘ ‘	‘input’, ‘specified’
strat_clouds_W	do_stochastic_clouds	activate the stochastic clouds module ?	.false.	
zetac_clouds_W	dummy	dummy variable	0	