EOCIS

EARTH OBSERVATION CLIMATE INFORMATION SERVICE

Quick Start Guide

Cloud properties, aerosol properties, Earth- and Surface-radiation budget from SLSTR

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1. Quick Start: Cloud, aerosol, Earth- and surface radiation products from SLSTR.

The following is intended to provide the user with sufficient information to quickly get to grips with the cloud properties, aerosol properties, Earth radiation budget and surface radiation budget products produced from the Sentinel-3 Sea and Land Surface Temperature Radiometer (SLSTR) using the Community Cloud retrieval for Climate (CC4Cl) processing scheme, and to gain some familiarity with the information available.

CC4Cl uses the Optimal Retrieval of Aerosol and Cloud (ORAC) scheme to produce Level-2 aerosol and cloud properties from SLSTR Level-1b data, and these products are used as input to the Bugsrad radiative transfer programme, which produces the Level-2 Earth- and surface radiation products. In this document we concentrate on the Level-3 products that are then produced and made available through EOCIS.

The data record produced for EOCIS spans from the start of 2017 until the end of 2024 and includes global observations from SLSTR on both Sentinel-3a and -3b.

1.1 What products are available?

There are two main Level-3 products available:

1. Monthly Level-3C averaged products on a 0.125°×0.125° latitude-longitude grid.
2. Daily Level-3U sampled products on a 0.05°×0.05° latitude-longitude grid.

Filenames are constructed as follows, using "-" (dash) as the primary field separator. Underscore is used within the primary fields to modify their meaning in some way:

[Date]-CC4CL-[L3 type]_[ECV]-[Product type]-[Product string]-[Algorithm]-[Version].nc

Where

- **[Date]:** For L3U this specifies the year (YYYY), month (MM), day (DD) of the observations in form YYYYMMDD; for L3C it specifies the year and month.
- **CC4CL:** Identifies the processing system – Community Cloud for Climate – used to produce the data.
- **[L3 type]**: The type of L3 file: "L3U" or "L3C" as described below.
- **[ECV]:** This identifies the essential climate variable which the file relates to. Can be "CLOUD" for cloud properties, "AEROSOL" for aerosol properties, "SRB" for surface radiation budget, or "ERB" for Earth Radiation Budget
- **[Product type]**: Identifies the main physical quantity in the file. This can be one of the following: "ap", "cee", "cer", "cfc", "chist", "cla", "cot", "cph", "cth", "ctp", "ctt", "cwp", "erb", "nobs", "srb" or "st". Each of these product types is defined in Table 1.
- **[Platform string]**: Identifies the sensor and platform used: "SLSTR_Sentinel3a", "SLSTR_Sentinel3b" (for products derived from the single sensor) or "SLSTR_Sentinel3a_b" (for products combining data from both SLSTR instruments).
- **[Algorithm]:** "ORAC" The retrieval algorithm used: Optimal Estimation of Aerosol and Cloud.
- **[Version]**: Version identifier.

1.2 Summary information

	ID	CC4CL L3 products
Main observed variables		**Cloud properties:**
	cfc	Cloud fractional cover
	cph	Cloud type (liquid water or ice)
	ctp	Cloud-top pressure
	cth	Cloud-top height
	ctt	Cloud-top temperature
	cot	Cloud optical depth
	cer	Cloud effective radius
	cla	Cloud albedo
	cee	Cloud emissivity
	cwp	Cloud water path (L3U)
	lwp	Cloud liquid water paths (L3C)
	iwp	Cloud ice water path (L3C)
	chist	Histograms of cloud properties and joint histogram of cloud optical depth and pressure (L3C)
		Aerosol properties:
	ap	Aerosol optical depth at 550 nm, effective radius. Over ocean, effective aerosol layer pressure, height and temperature.
		Cloud and Aerosol properties:
	st	Surface temperature. Provided for cloudy observations over land, and for all observations over the sea.
	qflag	Quality flag. Supplied as a bit-mask with individual meanings for cloud and aerosol retrievals (L3U)
		Earth radiation budget:
	erb	Top-of-atmosphere (TOA) up-welling short- and long-wave (i.e. solar and thermal-IR) radiation. TOA short-wave downwelling radiation. Values are included for both all-sky and clear-sky conditions.
		Surface radiation budget:
	srb	Bottom-of-atmosphere (BOA) up- and down-welling, short- and long-wave radiation. BOA down-welling photosynthetically active radiation (PAR). Values are included for both all-sky and clear-sky conditions.
Geographical range of dataset		Global
Temporal range of dataset		2017 to present
Spatial resolution / gridding		L3U: 0.05° × 0.05° latitude-longitude. L3C: 0.125° × 0.125° latitude-longitude.
Temporal sampling characteristics		L3U: Each file spans a day.

		L3C: Each file contains averages for a calendar month.
Level of processing		L3 gridded data.
Main auxiliary content		L3U: Uncertainties, sensing time, flags identifying certain conditions L3C aerosol and cloud products: Mean and standard deviation of the main variable ; mean uncertainty, propagated uncertainty assuming independent pixels, propagated uncertainty assuming correlation between pixels, number of samples.
Dataset citation		TBD
Dataset journal reference		[Various to be added]

Table 1 Summary Information for the L3 products

1.2.1 L3U Summary information

Table 3 summarises the variables within each of the L3U (daily) files. The left-hand column indicates either "Common" for variables present in most/all files or the specific filename variable ID. For the cloud ECV data, most files contain a single main physical variable together with its estimated random uncertainty, along with common variables defining the grid and providing quality information. For the aerosol, ERB and SRB ECV data (for which the number physical variables is small), each file contains the full suite of physical variables associated with the respective ECV.

In all cases the main physical variables have dimensions of **time** (which is always 1), **latitude** and **longitude**. Coordinate variables defining these are given in the file, with latitude and longitude being specified in units of degrees, while time is specified as a Julian-date in units of days since 1-Jan-1970. Additionally, all files contain the **mask** variable, which contains a bit mask of a binary cloud mask for the nadir (bit-1) and oblique (bit-2) views, as well as a land/sea mask (bit-3).

To reduce data volume, many variables are stored as integers with **scale_factor** and **add_offset**, which must be applied to convert the stored data type to physical values. This may be done automatically by the tool used to read the files (as is the case for the examples provided below

L3U files contain L2 retrieved values which have been subjected minimal quality control (the retrieval must have successfully converged a provided a reasonable fit to the satellite measurements). ***However, it is strongly recommended to apply further quality control to subset data***, based on the quality control flags contained within the **qcflag** file. The qcflags differ for the cloud and aerosol retrieval, as detailed in Table 2, but in both cases a qcflag of 0 (zero) indicates that all quality checks have been passed. The qcflag variable is encoded as a bit-mask, so that each pixel has a value which will return "true", or a positive value, when compared to the corresponding "flag mask" value using a bit-wise AND, if a given criterion is true. Note that failure to pass individual tests does not necessarily indicate a poor quality retrieval, but indicate situations where extra care should be taken in interpreting the results. For example, ORAC is relatively robust to the presence of sun-glint when performing a dual-view aerosol retrieval (as only one viewing direction will be glint-affected), but the retrieval of optical depth of thin cloud in glint effected pixels will be poorly constrained.

For in most situations the default filtering of pixels based on convergence and cost threshold should be sufficient for cloud retrievals. For aerosol, a stricter default criterion is recommended, including filtering for snow/ice surfaces, cloud adjacency and spikes in AOD; i.e. reject pixels for which (qcflag AND 271) is true.

It is also important to note that the quality file also contains several parameters which can be used to filter the data, including:

- A priori cost function. Tests consistency of the retrieval with prior constraints. Has an expectation value of 1 or less.
- Measurement cost function. Tests consistency of the retrieval with the measurement itself. Also has an expectation value of 1 or less (although values greater than 1 are often acceptable).

- Number of iterations. Indicates how quickly the retrieval converged to an optimal state estimate.
- Digital elevation model. Provides the terrain height of the underlying surface (ORAC does not take surface height into consideration in its radiative transfer calculations).
- Land-sea flag. Indicates whether a given pixel is deemed to be over land or water.

Furthermore, each aerosol and cloud parameter includes an uncertainty estimate, which is the level-2 optimal-estimation retrieval uncertainty, which indicates how well that parameter is constrained.

Flag mask	Flag meaning
	Cloud retrieval
1 (0000000001b)	Retrieval did not converge (failed)
2 (0000000010b)	Retrieval cost-function > 100 (poor fit)
4 (0000000100b)	Snow/Ice surface
8 (0000001000b)	Particle type disagrees with prior cloud mask
16 (0000010000b)	Degrees of freedom for noise > 1.0 (poorly constrained)
32 (0000100000b)	Surface elevation > 1.5 km
64 (0001000000b)	Possible sun glint
128 (0010000000b)	Retrieved state hit min/max limit.
	Aerosol retrieval
1 (0000000001b)	Retrieval did not converge (failed)
2 (0000000010b)	Retrieval cost-function > 3 (poor fit)
4 (0000000100b)	Snow/Ice surface
8 (0000001000b)	Cloud adjacent (at least 50% of neighbouring pixels are cloud)
16 (0000010000b)	Inhomogeneity (AOD stand deviation > 0.1 over 3x3 pixels)
32 (0000100000b)	Surface elevation > 1.5 km
64 (0001000000b)	Possible sun glint (in either nadir or oblique view)
128 (0010000000b)	Retrieval state hit min/max limit
256 (0100000000b)	Spike in AOD (failed morphological opening test)
512 (1000000000b)	Spike in effective radius (failed morphological opening test)

Table 2 Quality control flag bit-mask values for cloud and aerosol retrievals.

As the L3U data is a sampling of the L2 observations, rather than a spatial/temporal average like in L3C, the observations on the ascending-node (night-side) and descending-node (day-side) of the Sentinel-3 orbits (which, for a given location are separated by approximately 12 hours) are stored separately, and denoted by the suffixes "**_asc**" and "**_desc**" to their variable names. Mostly, but not exclusively, daylight observations will be found in the descending node observations, while the ascending node will be dominated by night-time observations.

Filename variable ID	Variable name	Description	Dimensions	Units
Common	time	Time of start of sampling period	time	days since 1970-01-01T00:00:00Z
Common	lon	Centre longitude of grid cell	lon	Degrees East
Common	lat	Centre latitude of grid cell	lat	Degrees North
Common	mask	Binary cloud and land masks, stored as a bit mask: bit 1 =True: cloud in ascending node bit 2 = True: cloud in descending node bit 3 = True: pixel is land bit 4 = True: pixel has dual-view	time lat lon	-
geom	solarzen_asc_view1	Solar zenith angle, ascending, for nadir view	time lat lon	degrees
geom	solarzen_desc_view1	Solar zenith angle, descending, for nadir view	time lat lon	degrees
geom	solarzen_asc_view2	Solar zenith angle, ascending, for oblique view	time lat lon	degrees
geom	solarzen_desc_view2	Solar zenith angle, descending, for oblique view	time lat lon	degrees
geom	satzen_asc_view1	Satellite zenith angle, ascending, for nadir view	time lat lon	degrees
geom	satzen_desc_view1	Satellite zenith angle, descending, for nadir view	time lat lon	degrees
geom	satzen_asc_view2	Satellite zenith angle, ascending, for oblique view	time lat lon	degrees
geom	satzen_desc_view2	Satellite zenith angle, descending, for oblique view	time lat lon	degrees
geom	relazi_asc_view1	Relative azimuth between sun and satellite, ascending, for nadir view	time lat lon	degrees
geom	relazi_desc_view1	Relative azimuth between sun and satellite, descending, for nadir view	time lat lon	degrees
geom	relazi_asc_view2	Relative azimuth between sun and satellite, ascending, for oblique view	time lat lon	degrees
geom	relazi_desc_view2	Relative azimuth between sun and satellite, descending, for oblique view	time lat lon	degrees
time	time_asc	Pixel measurement time, ascending	time lat lon	degrees

time	time_desc	Pixel measurement time, descending	time lat lon	degrees
quality	qcflag_asc	Quality flag for cloud and aerosol, ascending	time lat lon	-
quality	qcflag_desc	Quality flag for cloud and aerosol, ascending	time lat lon	-
quality	illum_asc	Illumination condition, ascending: 1 = daylight, 2 = twilight, 3 = night	lon lat time	-
quality	illum_desc	Illumination condition, descending: 1 = daylight, 2 = twilight, 3 = night	lon lat time	-
ap	aod550_asc	Aerosol optical depth at 550 nm, ascending	time lat lon	-
ap	aod550_desc	Aerosol optical depth at 550 nm, descending	time lat lon	-
ap	aod550_asc_unc	Uncertainty in aod550, ascending	time lat lon	-
ap	aod550_desc_unc	Uncertainty in aod550, descending	time lat lon	-
ap	aer_asc	Aerosol effective radius, ascending	time lat lon	µm
ap	aer_desc	Aerosol effective radius, descending	time lat lon	µm
ap	aer_asc_unc	Uncertainty in aer, ascending	time lat lon	µm
ap	aer_desc_unc	Uncertainty in aer, descending	time lat lon	µm
ap	alp_asc	Aerosol layer pressure, ascending	time lat lon	hPa
ap	alp_desc	Aerosol layer pressure, descending	time lat lon	hPa
ap	alp_asc_unc	Uncertainty in alp, ascending	time lat lon	hPa
ap	alp_desc_unc	Uncertainty in alp, descending	time lat lon	hPa
ap	alh_asc	Aerosol layer height, ascending	time lat lon	km
ap	alh_desc	Aerosol layer height, descending	time lat lon	km
ap	alh_asc_unc	Uncertainty in alh, ascending	time lat lon	km
ap	alh_desc_unc	Uncertainty in alh, descending	time lat lon	km
ap	alt_asc	Aerosol layer temperature, ascending	time lat lon	K
ap	alt_desc	Aerosol layer temperature, descending	time lat lon	K
ap	alt_asc_unc	Uncertainty in alt, ascending	time lat lon	K
ap	alt_asc_unc	Uncertainty in alt, descending	time lat lon	K
cee	cee_asc	Cloud effective emissivity at 10.8 µm, ascending	time lat lon	1

cee	cee_desc	Cloud effective emissivity at 10.8 µm, descending	time lat lon	1
cee	cee_asc_unc	Uncertainty in cee, ascending	time lat lon	1
cee	cee_desc_unc	Uncertainty in cee, descending	time lat lon	1
cer	cer_asc	Cloud effective radius, ascending	time lat lon	µm
cer	cer_desc	Cloud effective radius, descending	time lat lon	µm
cer	cer_asc_unc	Uncertainty in cer, ascending	time lat lon	µm
cer	cer_desc_unc	Uncertainty in cer, descending	time lat lon	µm
cla	cla_vis006_asc	Cloud albedo at 600 nm, ascending	time lat lon	1
cla	cla_vis006_desc	Cloud albedo at 600 nm, descending	time lat lon	1
cla	cla_vis006_asc_unc	Uncertainty in cla_vis006, ascending	time lat lon	1
cla	cla_vis006_desc_unc	Uncertainty in cla_vis006, descending	time lat lon	1
cla	cla_vis008_asc	Cloud albedo at 800 nm, ascending	time lat lon	1
cla	cla_vis008_desc	Cloud albedo at 800 nm, descending	time lat lon	1
cla	cla_vis008_asc_unc	Uncertainty in cla_vis008, ascending	time lat lon	1
cla	cla_vis008_desc_unc	Uncertainty in cla_vis008, descending	time lat lon	1
cot	cot_asc	Cloud optical thickness, ascending	time lat lon	-
cot	cot_desc	Cloud optical thickness, descending	time lat lon	-
cot	cot_asc_unc	Uncertainty in cot, ascending	time lat lon	-
cot	cot_desc_unc	Uncertainty in cot, descending	time lat lon	-
cph	cph_asc	Cloud phase, ascending 1 = liquid water, 2 = ice	time lat lon	-
cph	cph_desc	Cloud phase, descending 1= liquid water, 2 = ice	time lat lon	-
cph	cty_asc	Cloud type according to Pavolonis classification, ascending: 0 = clear-sky 1 = switched_to_liquid 2 = fog 3 = liquid 4 = super-cooled liquid 5 = switched_to_ic 6 = opaque_ice 7 = cirrus 8 = overlap	time lat lon	-

		9 = probably_opaque_ice		
cph	cty_desc	Cloud type according to Pavolonis classification, descending.	time lat lon	-
cth	cth_asc	Cloud-top height, ascending	time lat lon	km
cth	cth_desc	Cloud-top height, descending	time lat lon	km
cth	cth_asc_unc	Uncertainty in cth, ascending	time lat lon	km
cth	cth_desc_unc	Uncertainty in cth, descending	time lat lon	km
ctp	ctp_asc	Cloud-top pressure, ascending	time lat lon	hPa
ctp	ctp_desc	Cloud-top pressure, descending	time lat lon	hPa
ctp	ctp_asc_unc	Uncertainty in ctp, ascending	time lat lon	hPa
ctp	ctp_desc_unc	Uncertainty in ctp, descending	time lat lon	hPa
ctt	ctt_asc	Cloud-top temperature, ascending	time lat lon	K
ctt	ctt_desc	Cloud-top temperature, descending	time lat lon	K
ctt	ctt_asc_unc	Uncertainty in ctt, ascending	time lat lon	K
ctt	ctt_desc_unc	Uncertainty in ctt, descending	time lat lon	K
cwp	cwp_asc	Cloud water path, ascending	time lat lon	g m^{-2}
cwp	cwp_desc	Cloud water path, descending	time lat lon	g m^{-2}
cwp	cwp_asc_unc	Uncertainty in cwp, ascending	time lat lon	g m^{-2}
cwp	cwp_desc_unc	Uncertainty in cwp, descending	time lat lon	g m^{-2}
st	stemp_asc	Surface temperature, ascending	time lat lon	K
st	stemp_desc	Surface temperature, descending	time lat lon	K
st	stemp_asc_unc	Uncertainty in stemp, ascending	time lat lon	K
st	stemp_desc_unc	Uncertainty in stemp, descending	time lat lon	K
erb	toa_lwup_asc	Top-of-atmosphere upwelling longwave radiation, ascending (outgoing longwave radiation – OLR)	time lat lon	W m^{-2}
erb	toa_lwup_desc	Top-of-atmosphere upwelling longwave radiation (outgoing longwave radiation – OLR) , descending	time lat lon	W m^{-2}
erb	toa_swdn_asc	Top-of-atmosphere downwelling shortwave radiation (incoming solar flux), ascending	time lat lon	W m^{-2}
erb	toa_swdn_desc	Top-of-atmosphere downwelling shortwave radiation (incoming solar flux), descending	time lat lon	W m^{-2}
erb	toa_swup_asc	Top-of-atmosphere upwelling shortwave radiation (reflected solar	time lat lon	W m^{-2}

		flux - RSF), ascending		
erb	toa_swup_desc	Top-of-atmosphere upwelling shortwave radiation (reflected solar flux - RSF), descending	time lat lon	W m^{-2}
srb	boa_lwdn_asc	Bottom-of-atmosphere downwelling longwave radiation, all-sky (surface downwelling longwave - SDL), ascending	time lat lon	W m^{-2}
srb	boa_lwdn_desc	Bottom-of-atmosphere downwelling longwave radiation, all-sky (surface downwelling longwave - SDL), descending	time lat lon	W m^{-2}
srb	boa_lwup_asc	Bottom-of-atmosphere upwelling longwave radiation, all-sky (surface outgoing longwave, SOL), ascending	time lat lon	W m^{-2}
srb	boa_lwup_desc	Bottom-of-atmosphere upwelling longwave radiation, all-sky (surface outgoing longwave, SOL), descending	time lat lon	W m^{-2}
srb	boa_swdn_asc	Bottom-of-atmosphere downwelling shortwave radiation, all-sky (surface incoming solar, SIS), ascending	time lat lon	W m^{-2}
srb	boa_swdn_desc	Bottom-of-atmosphere downwelling shortwave radiation, all-sky (surface incoming solar, SIS), descending	time lat lon	W m^{-2}
srb	boa_swup_asc	Bottom-of-atmosphere upwelling shortwave radiation, all-sky (surface reflected solar, SRS), ascending	time lat lon	W m^{-2}
srb	boa_swup_desc	Bottom-of-atmosphere upwelling shortwave radiation, all-sky (surface reflected solar, SRS), descending	time lat lon	W m^{-2}
srb	boa_par_tot_asc	Bottom-of-atmosphere, total downwelling photosynthetically active radiation, ascending	time lat lon	W m^{-2}
srb	boa_par_tot_desc	Bottom-of-atmosphere, total downwelling photosynthetically active	time lat lon	W m^{-2}

		radiation, descending		
srb	boa_par_dif_asc	Bottom-of-atmosphere, diffuse downwelling photosynthetically active radiation, ascending	time lat lon	W m^{-2}
srb	boa_par_dif_desc	Bottom-of-atmosphere, diffuse downwelling photosynthetically active radiation, descending	time lat lon	W m^{-2}

Table 3 Summary information for each variable for L3U products. Most variables are segregated into the ascending (where the satellite is travelling north in its orbit) and descending (where the satellite is travelling south) halves of the orbit. For Sentinel-3, most of the descending node is in daylight, while ascending is on the night-side of the planet, but both sections can have either day or night observations near the poles, depending on the time of year.

1.2.2 L3C Summary information

The L3C files contain monthly averaged data accumulated as follows, with all variables defined in Table 4:

- ORAC L2 files are used for input.
- L3C is computed on a 0.125°×0.125° latitude-longitude grid. Each L2 file is read in turn and running totals of the data, data-squared and uncertainties are calculated, along with counts of each data type in each grid cell.
  For L3C, quality control is applied to both cloud and aerosol data before they are included in running averages, and only data which passes either of these quality control steps is included in the radiative flux averages.
- Once all L2 data for the given month has been read, the running totals and pixel counts are used to calculate the output variables described in Table 4.
- In addition to mean values, comprehensive uncertainty statistics are provided for most variables (which are described below).
- Additionally, histograms describing the distribution of cloud parameters in each grid are provided in the “chist” file, as described in

In all cases the main physical variables have dimensions of **time** (which is always 1), **lat** (latitude) and **lon** (longitude). Coordinate variables defining these are given in the file, with latitude and longitude being specified in units of degrees, while time is specified as a Julian-date in units of days since 1-Jan-1970. In addition the chist file contains the following coordinate variables defining the histogram vertices:

- **hist_phase:** Defines the phase dimension (water/ice) of all histograms.
- **hist1d_cot_bin_centre**:
  hist1d_cot_bin_border: Define the cloud optical depth histograms (14 bins)
- **hist1d_cla_vis006_bin_centre**:
  hist1d_cla_vis006_bin_border: Define the histograms of cloud albedo in the visible (600 nm wavelength, 13 bins).
- **hist1d_cla_vis008_bin_centre**:
  hist1d_cla_vis008_bin_border: Define the histograms of cloud albedo in the near-IR (800 nm wavelength, 13 bins).
- **hist1d_cer_bin_centre:**
  hist1d_cer_bin_border: Define the cloud effective radius histograms (11 bins).
- **hist1d_cwp_bin_centre:**
  hist1d_cwp_bin_border: Define the cloud water path histograms (14 bins).
- **hist1d_ctp_bin_centre:**
  hist1d_ctp_bin_border: Define the cloud top pressure histograms (15 bins).
- **hist1d_ctt_bin_centre:**
  hist1d_ctt_bin_border: Define the cloud top temperature histograms (16 bins).
- **hist2d_cot_bin_centre**:
  hist2d_cot_bin_border:
  hist2d_ctp_bin_centre:
  hist2d_ctp_bin_border: Define the cloud optical depth/cloud top pressure joint histograms (13×15 bins).

Product ID	Variable name	Description	Dimensions	Units
Common	time	Time of start of sampling period	time (coordinate)	Days since 1970-01-01 T00:00:00Z
Common	lon	Centre longitude of grid cell	lon	Degrees East
Common	lat	Centre latitude of grid cell	lat	Degrees North
nobs	nobs	Total number of L2 pixels included in the grid cell.	time, lat, lon	-
nobs	nobs_cloudy	Number of L2 pixels flagged as cloudy.	time, lat, lon	-
nobs	nobs_day	Number of L2 daylight pixels (solar zenith $< 75°$).	time, lat, lon	-
nobs	nobs_clear_day	Number of L2 daylight pixels flagged as cloud-free.	time, lat, lon	-
nobs	nobs_cloudy_day	Number of L2 daylight pixels flagged as cloudy.	time, lat, lon	-
nobs	nobs_clear_night	Number of L2 nighttime pixels (solar zenith $\geq 90°$) flagged as clear.	time, lat, lon	-
nobs	nobs_cloudy_night	Number of L2 nighttime pixels flagged as cloudy.	time, lat, lon	-
nobs	nobs_clear_twl	Number of L2 twilight pixels ($75° \leq$ solar zenith $\leq 90°$) flagged as clear.	time, lat, lon	-
nobs	nobs_cloudy_twl	Number of L2 twilight pixels flagged as cloudy.	time, lat, lon	-
nobs	nretr_cloudy	Number of valid cloud retrievals.	time, lat, lon	-
nobs	nretr_cloudy_liq	Number of valid liquid-water cloud retrievals.	time, lat, lon	-
nobs	nretr_cloudy_ice	Number of valid ice cloud retrievals.	time, lat, lon	-
nobs	nretr_cloud_day	Number of daylight pixel with valid cloud retrievals.	time, lat, lon	-
nobs	nretr_cloudy_day_liq	Number of daylight pixel with valid liquid-water cloud retrievals.	time, lat, lon	-
nobs	nretr_cloudy_day_ice	Number of daylight pixel with valid ice cloud retrievals.	time, lat, lon	-
nobs	nretr_cloudy_low	Number of valid low-level (ctp $>$ 680 hPa) cloud retrievals.	time, lat, lon	-
nobs	nretr_cloudy_mid	Number of valid mid-level ($440 \leq$ ctp ≤ 680 hPa) cloud retrievals	time, lat, lon	-

nobs	nretr_cloudy_high	Number of valid high (ctp < 440 hPa) cloud retrievals.	time, lat, lon	-
nobs	nretr_aerosol	Number of valid aerosol retrievals.	time, lat, lon	-
Common	[variable]	Mean value of variable.	time, lat, lon	Varies
Common	[variable]_std	Standard deviation of [variable]	time, lat, lon	As [variable]
Common	[variable]_unc	Mean of L2 uncertainty on [variable]	time, lat, lon	As [variable]
Common	[variable]_prop_unc	Propagated uncertainty on mean value of [variable], assuming independent pixels.	time, lat, lon	As [variable]
Common	[variable]_corr_unc	Propagated uncertainty on mean value of [variable], assuming correlation	time, lat, lon	As [variable]
ap	aod550 (all common variables)	Aerosol optical depth at 550 nm	time, lat, lon	-
ap	aer (all common variables)	Aerosol effective radius	time, lat, lon	µm
ap	alp (all common variables)	Aerosol layer pressure	time, lat, lon	hPa
ap	alh (all common variables)	Aerosol layer height	time, lat, lon	km
ap	alt (all common variables)	Aerosol layer temperature	time, lat, lon	K
cee	cee (all common variables)	Cloud effective emissivity at 10.8 µm	time, lat, lon	1
cer	cer (all common variables)	Cloud effective radius	time, lat, lon	µm
cer	cer_ice (all common variables)	Cloud effective radius for ice clouds	time, lat, lon	µm
cer	cer_liq (all common variables)	Cloud effective radius for liquid water clouds	time, lat, lon	µm
cfc	cfc (all common variables)	Cloud fractional cover	time, lat, lon	1
cfc	cfc_day (mean value only)	Cloud fractional cover for daylight pixels	time, lat, lon	1
cfc	cfc_night (mean value only)	Cloud fractional cover for nighttime pixels	time, lat, lon	1
cfc	cfc_twl (mean value only)	Cloud fractional cover for twilight pixels	time, lat, lon	1
cfc	cfc_low (mean value only)	Cloud fractional cover, low-level clouds	time, lat, lon	1
cfc	cfc_mid (mean value only)	Cloud fractional cover, mid-level clouds	time, lat, lon	1
cfc	cfc_high (mean value only)	Cloud fractional cover, high-level clouds	time, lat, lon	1
cla	cla_vis006 (all common variables)	Cloud albedo at 600 nm	time, lat, lon	1
cla	cla_vis008 (all common variables)	Cloud albedo at 800 nm	time, lat, lon	1
cla	cla_vis006_ice (mean, _std and _unc only)	Cloud albedo at 600 nm for ice clouds	time, lat, lon	1

cla	cla_vis006_liq (mean, _std and _unc	Cloud albedo at 600 nm for liquid water clouds	time, lat, lon	1
cla	cla_vis008_ice (mean, _std and _unc only)	Cloud albedo at 800 nm for ice clouds	time, lat, lon	1
cla	cla_vis008_liq (mean, _std and _unc only)	Cloud albedo at 800 nm for liquid water clouds	time, lat, lon	1
cot	cot (all common variables)	Cloud optical thickness	time, lat, lon	1
cot	cot_log (mean value only)	Cloud optical thickness logarithmically averaged	time, lat, lon	1
cot	cot_ice (all common variables)	Ice cloud optical thickness	time, lat, lon	1
cot	cot_liq (all common variables)	Liquid water cloud optical thickness	time, lat, lon	1
cph	cph (all common variables)	Fraction of liquid water clouds	time, lat, lon	1
cph	cph_day (all common variables)	Fraction of liquid water clouds for daylight pixels	time, lat, lon	1
cth	cth (all common variables)	Cloud top height	time, lat, lon	km
ctp	ctp (all common variables)	Cloud top pressure	time, lat, lon	hPa
ctp	ctp_log (mean value only)	Cloud top pressure logarithmically averaged	time, lat, lon	hPa
ctt	ctt (all common variables)	Cloud top temperature	time, lat, lon	K
cwp	iwp (all common variables)	Ice water path	time, lat, lon	$g\ m^{-2}$
cwp	iwp_allsky (mean value only)	Mean ice water path over all L2 pixels in grid cell	time, lat, lon	$g\ m^{-2}$
cwp	lwp (all common variables)	Liquid water path	time, lat, lon	$g\ m^{-2}$
cwp	lwp_allsky (mean value only)	Mean liquid water path over all pixels in grid cell	time, lat, lon	$g\ m^{-2}$
chist	hist1d_cer	Histogram of cloud effective radius in each grid cell	time, hist_phase, hist1d_cer_bin_centre, lat, lon	-
chist	hist1d_cla_vis006	Histogram of cloud albedo at 600 nm in each grid cell	time, hist_phase, hist1d_cla_bin_centre, lat,lon	-
chist	hist1d_cla_vis008	Histogram of cloud albedo at 800 nm in each grid cell	time, hist_phase, hist1d_cla_bin_centre, lat,lon	-
chist	hist1d_cot	Histogram of cloud optical thickness in each grid cell	time, hist_phase, hist1d_cot_bin_centre, lat,lon	-

chist	hist1d_ctp	Histogram of cloud top pressure in each grid cell	time, hist_phase, hist1d_ctp_bin_centre, lat,lon	-
chist	hist1d_ctt	Histogram of cloud top temperature in each grid cell	time, hist_phase, hist1d_ctt_bin_centre, lat,lon	-
chist	hist1d_cwp	Histogram of cloud water path in each grid cell	time, hist_phase, hist1d_cwp_bin_centre, lat,lon	-
chist	hist2d_cot_ctp	Joint histogram of cloud optical depth and cloud top pressure in each grid cell	time, hist_phase, hist2d_ctp_bin_centre, hist2d_cot_bin_centre, lat,lon	-
st	stemp (all common variables)	Surface temperature (all pixels over ocean, cloud pixels over land)	time, lat, lon	K
erb	toa_lwup (mean and _std only)	Top-of-atmosphere upwelling longwave radiation, all-sky (outgoing longwave radiation - OLR)	time, lat, lon	W m^{2}
erb	toa_lwup_clear (mean and _std only)	Top-of-atmosphere upwelling longwave radiation, clear-sky	time, lat, lon	W m^{2}
erb	toa_lwup_low (mean and _std only)	Top-of-atmosphere upwelling longwave radiation, low-level clouds	time, lat, lon	W m^{2}
erb	toa_lwup_mid (mean and _std only)	Top-of-atmosphere upwelling longwave radiation, mid-level clouds	time, lat, lon	W m^{2}
erb	toa_lwup_hig (mean and _std only)	Top-of-atmosphere upwelling longwave radiation, high-level clouds	time, lat, lon	W m^{2}
erb	toa_swdn (mean and _std only)	Top-of-atmosphere downwelling shortwave radiation (incoming solar flux)	time, lat, lon	W m^{2}
erb	toa_swup (mean and _std only)	Top-of-atmosphere upwelling shortwave radiation, all-sky (reflected solar flux – RSF)	time, lat, lon	W m^{2}

erb	toa_swup_clr (mean and _std only)	Top-of-atmosphere upwelling shortwave radiation, clear-sky	time, lat, lon	W m^2
erb	toa_swup_low (mean and _std only)	Top-of-atmosphere upwelling shortwave radiation, low-level clouds	time, lat, lon	W m^2
erb	toa_swup_mid (mean and _std only)	Top-of-atmosphere upwelling shortwave radiation, mid-level clouds	time, lat, lon	W m^2
erb	toa_swup_hig (mean and _std only)	Top-of-atmosphere upwelling shortwave radiation, high-level clouds	time, lat, lon	W m^2
srb	boa_lwdn (mean and _std only)	Bottom-of-atmosphere downwelling longwave radiation, all-sky (surface downwelling longwave, SDL)	time, lat, lon	W m^2
srb	boa_lwdn_clr (mean and _std only)	Bottom-of-atmosphere downwelling longwave radiation, clear-sky	time, lat, lon	W m^2
srb	boa_lwup (mean and _std only)	Bottom-of-atmosphere upwelling longwave radiation, all-sky (surface outgoing longwave, SOL)	time, lat, lon	W m^2
srb	boa_lwup_clr (mean and _std only)	Bottom-of-atmosphere upwelling longwave radiation, clear-sky	time, lat, lon	W m^2
srb	boa_swdn (mean and _std only)	Bottom-of-atmosphere downwelling shortwave radiation, all-sky (surface incoming solar, SIS)	time, lat, lon	W m^2
srb	boa_swdn_clr (mean and _std only)	Bottom-of-atmosphere downwelling shortwave radiation, clear-sky	time, lat, lon	W m^2
srb	boa_swup (mean and _std only)	Bottom-of-atmosphere upwelling shortwave radiation, all-sky (surface reflected solar, SRS)	time, lat, lon	W m^2
srb	boa_swup_clr (mean and _std only)	Bottom-of-atmosphere upwelling shortwave radiation, clear-sky	time, lat, lon	W m^2
srb	boa_par_tot	Bottom-of-atmosphere, total downwelling photosynthetically active radiation	time, lat, lon	W m^2
srb	boa_par_diff	Bottom-of-atmosphere, diffuse downwelling photosynthetically active radiation	time, lat, lon	W m^2

Table 4 Summary information for each variable for L3C products. Note that the "common" variables indicate the statistical parameters provided for each main geophysical parameter (as specified for each variable in the table). Some variables are described as "logarithmically averaged", which means the mean of n values of x is calculated using the expression:

$$\hat{x}_{log} = exp(\Sigma_{i=1}^{n} ln(x_i)) / n$$

1.3 What can these products be used for?

These products can be used for a wide range of scientific studies, on scales of ~1km to global and daily to multi-annual. The inclusion of radiatively consistent aerosol and cloud properties, along with consistent estimates of top- and bottom-of-atmosphere radiative fluxes, makes the product particularly well suited to radiative effect and forcing studies. As the data record grows in length, temporally speaking, it will become increasingly suitable for detection and characterisation of anomalies and long-term changes, particularly if taken in conjunction with data derived from the Along Track Scanning Radiometer (ATSR) instruments which preceded SLSTR, however the five-year gap between the end of the Advanced-ATSR record and the beginning of the SLSTR record makes it difficult to ensure consistency between these two records.

The inclusion of radiative fluxes at the surface also makes the product potentially useful for non-atmospheric studies as well. For example monitoring the multi-annual insolation, or photosynthetically active radiation, which could be helpful for planning solar energy generation or monitoring crop health and productivity.

1.4 Where to find these products for download

These products can be accessed from the following location using the links below:

L3C: https://gws-access.jasmin.ac.uk/public/cds_c3s_cloud/eocis/L3C/

L3U: https://gws-access.jasmin.ac.uk/public/cds_c3s_cloud/eocis/L3U/

(To be updated with CEDA link when archived)

1.5 Using downloaded data

Examples are given below of use and basic manipulation of the data using python.

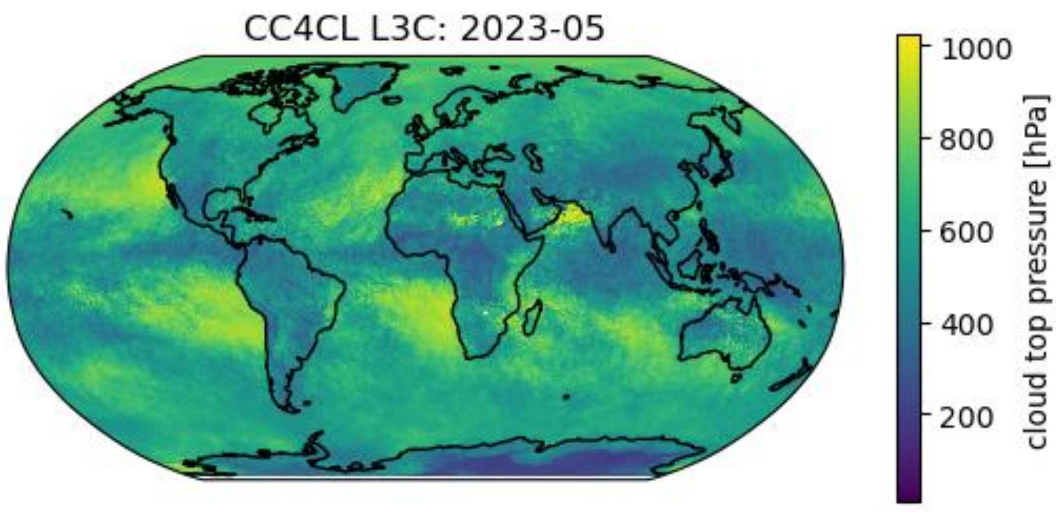
1.5.1 Import and plot L3C data

The following code uses the xarray, matplotlib and cartopy python modules to read and display a map of the monthly mean cloud-top pressure from L3C data.

Example Code:

```
import xarray as xr
import matplotlib.pyplot as plt
import cartopy.crs as crs
import numpy as np
# Open total precipitable water vapour file:
 filename = 'L3C/SLSTR_Sentinel3a/v5.0/2023/05/202305-CC4CL-L3C_CLOUD-ctp-
SLSTR_Sentinel3a-ORAC-fv5.0.nc'
d = xr.open_dataset(filename)
# Data fields have a time-dimension, of length-1, for archival purposes. Use
the numpy squeeze function to remove this dimension for plotting.
ctp = np.squeeze(d.ctp)
# Set up a map to display the data on
ax = plt.axes(projection=crs.Robinson())
# Use the plot method of the ctp xarray to project the data onto our map.
# Also, scale the colour-bar so it is not too large.
ctp.plot.imshow(x='lon', y='lat', ax=ax, transform=crs.PlateCarree(),
cbar_kwargs={'shrink':0.6})
# Add coastlines to the map
ax.coastlines()
# Set a title for the map
plt.title("CC4CL L3C: 2023-05")
# Display the map
plt.show()
```

Illustrative Results:



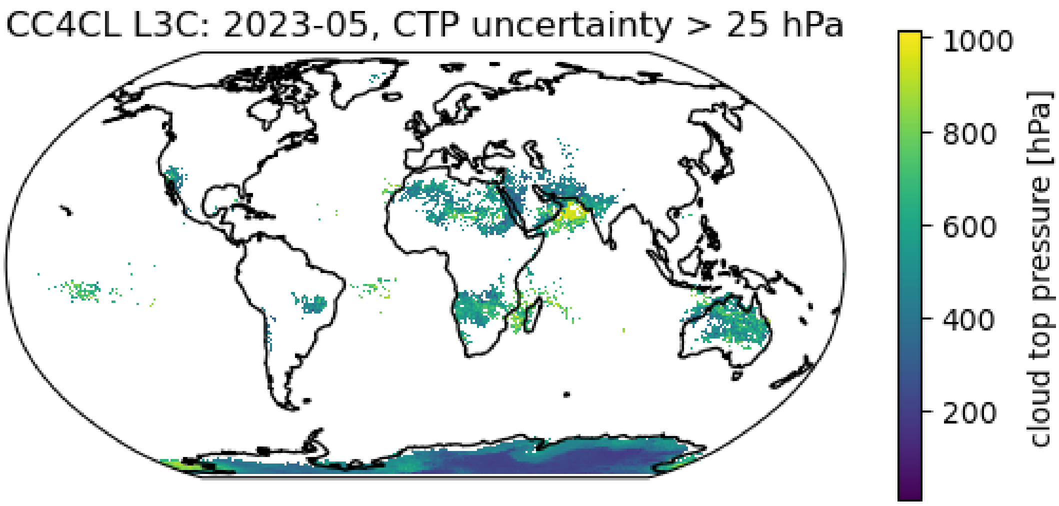
1.5.2 Import, filter and plot L3C data

This example is similar to the basic plotting, shown in the previous section, but here we isolate areas when the monthly cloud-top pressure is particularly uncertain. The resulting plot shows a significant correspondence between regions with a high surface reflectance (deserts and Antarctica) with high-uncertainty in cloud-top-pressure.

Example Code:

```
import xarray as xr
import matplotlib.pyplot as plt
import cartopy.crs as crs
import numpy as np
# Open total precipitable water vapour file:
 filename = 'L3C/SLSTR_Sentinel3a/v5.0/2023/05/202305-CC4CL-L3C_CLOUD-ctp-SLSTR_Sentinel3a-ORAC-fv5.0.nc'
d = xr.open_dataset(filename)
# Filter the data, based on the propagated uncertainty value, and apply the "squeeze" function to remove time coordinate.
ctp = np.squeeze(d.ctp.where(d.variables['ctp_prop_unc'][:] >= 25)[:])
# Set up a map to display the data on
ax = plt.axes(projection=crs.Robinson())
# Use the plot method of the ctp xarray to project the data onto our map.
# Also, scale the colour-bar so it is not too large.
ctp.plot.imshow(x='lon', y='lat', ax=ax, transform=crs.PlateCarree(), cbar_kwargs={'shrink':0.6})
# Add coastlines to the map
ax.coastlines()
# Set a title for the map
plt.title("CC4CL L3C: 2023-05, CTP uncertainty > 25 hPa")
# Display the map
plt.show()
```

Illustrative Results:



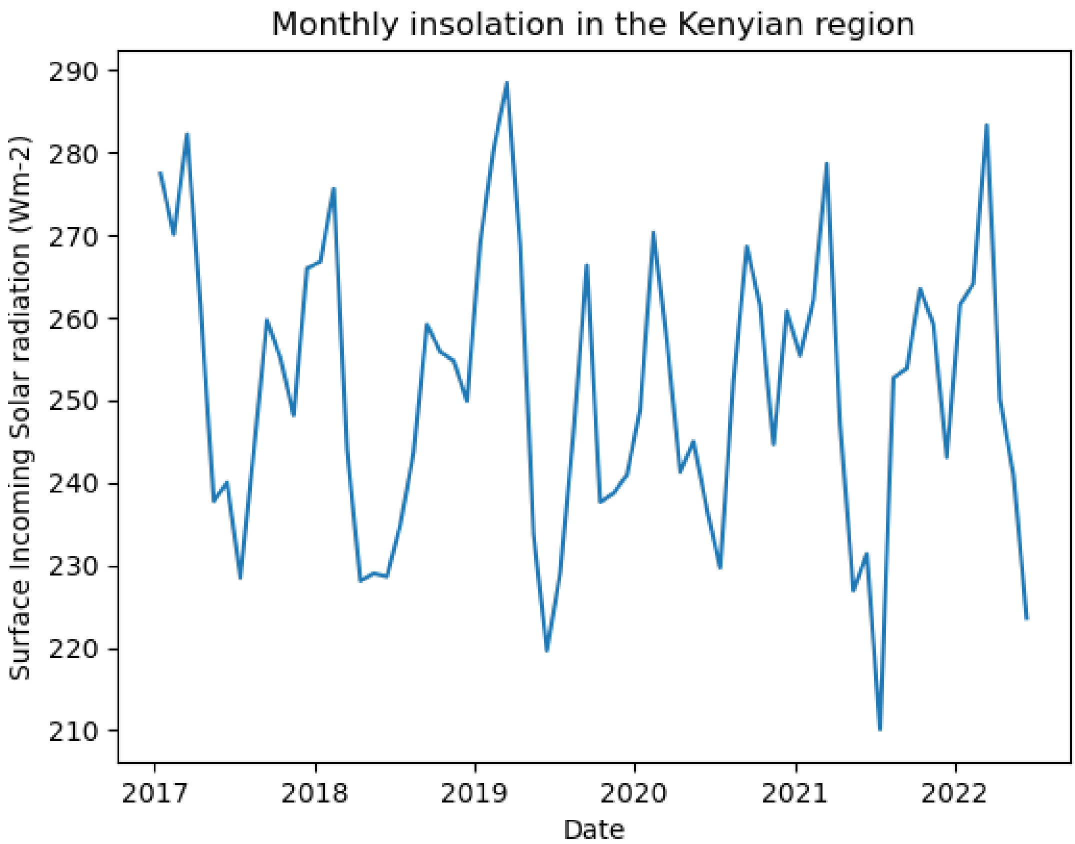
1.5.3 Plot a timeseries of data averaged over a latitude-longitude box

This example demonstrates how easily data across the period of the dataset can be spatially averaged to produce time-series over specific regions.

Example Code:

```
from glob import glob
import xarray as xr
import matplotlib.pyplot as plt
import numpy as np
# Get a list of all L3C surface radiative flux data, and sort them (by date).
files = glob('L3C/SLSTR_Sentinel3a/v5.0/*/*/*-CC4CL-L3C_SRB-srb-
SLSTR_Sentinel3a-ORAC-fv5.0.nc')
file.sort()
# Open all these files as a single dataset, concatenating them in the
# time-dimension.
d = xr.open_mfdataset(files, concat_dim='time', combine='nested')
# Apply geographic limits to these data, focusing on a region centred on
# Kenya in Eastern Africa.
sis = d.sis.where(d.lat > -5).where(d.lat < 5).where(d.lon > 30).where(d.lon <
45)
ax = plt.axes(projection=crs.Robinson())
# Average the data across the latitude and longitude dimensions.
Meansis = np.mean(sis, axis=[1,2])
# Plot the resulting time-series, after setting titles and axis-labels.
plt.title('Monthly insolation in the Kenyian region')
plt.ylabel('Surface Incoming Solar radiation (Wm-2)')
plt.xlabel('Date')
plt.show()
```

Illustrative Results:



1.6 Interactive visualisation / data access

Data can be visualised using standard netcdf tools such as panoply, ncview etc.

1.7 Your obligations when using these products

By accessing the CC4CL products, you agree to cite the dataset digital object identifier (doi) and corresponding journal article describing the dataset every time you publish results obtained in whole or in part by use of UK EOCIS products. These citations are given under Summary Information.

The reference to the dataset should mention "created by the UK Earth Observation Climate Information Service". The product name and acronym in Table 1 and should be used to avoid confusion and enable traceability.

1.8 Further Information

This dataset is scheduled to be brokered to the European Union Copernicus Climate Change Service (C3S), and production of the data will continue to extend this record on the C3s Climate Data Store (CDS). Users interested in data beyond after the end of the 2017-2024 time span of the EOCIS dataset should check the C3S CDS, and search for “cloud properties”, “aerosol properties”, “Earth radiation budget” or “surface radiation budget” here: https://cds.climate.copernicus.eu/

History of modifications / Change Log

Version	Date	Changes	Person
0.1	31 October 2024	Initial Draft	R.S.

Related Documents / Reference Documents

Document	Author	Reference
Water Vapour CCI: Algorithm Theoretical Basis Document (ATBD) Part 2 - IMS L2 Product **https://climate.esa.int/documents/2497/** **Water_Vapour_CCI_D2.2_ATBD_Part2-IMS_L2_product_v2.0.pdf**	R. Siddans	RD1
RAL Methane Retrieval ATBD's: IASI version 2.1: https://methaneplus.eu/Docs/RAL_IASI_CH4_ATBD_v2p1.pdf	R. Siddans	RD2

Acronyms and/or Abbreviations

Acronym / Abbreviation	Definition
ATBD	Algorithm Theoretical Basis Document
IMS	Infra-red Microwave Sounder retrieval scheme
….	

General definitions

Term	Definition