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## ERA5-Land: data documentation

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### Introduction

Here we document the **ERA5-Land** dataset that, in its consolidated version, covers the period from January 1950 to 2-3 months before the present. In addition, the **ERA5-Land-T** version delivers non-checked close to Near-Real-Time (NRT) daily updates. ERA5-Land-T is synchronized with the close to NRT daily updates provided by the ERA5 climate reanalysis (ERA5T).

ERA5-Land is a replay of the land component of the ERA5 climate reanalysis, forced by meteorological fields from ERA5. Note that ERA5-Land always uses forcing fields based on the final release of ERA5 (i.e., expver=0001). ERA5-Land comes with a series of improvements making it more accurate for all types of land applications. In particular, ERA5-Land runs at enhanced resolution (9 km vs 31 km in ERA5). The temporal frequency of the output is hourly and the fields are masked for all oceans, making them lighter to handle. Click [this link here](#) for comparison of the ERA5-Land features against other ECMWF reanalyses.

ERA5-Land is produced under a single simulation, without coupling to the atmospheric module of the ECMWF's Integrated Forecasting System (IFS) or to the ocean wave model of the IFS. **It runs without data assimilation**, making it computationally affordable for relatively quick updates. For example, if significant improvements of the land surface model are implemented, the whole or part of the dataset can be reprocessed in a relatively short period. Also, updates are possible in case improved auxiliary datasets are used as input for the production.

⚠ Observations indirectly influence the simulation through the atmospheric forcing of ERA5. This forcing drives the ERA5-Land single simulation and it has been obtained by assimilating observations through a 4D-VAR data assimilation system and a Simplified Extended Kalman Filter.

The core of ERA5-Land is the Tiled ECMWF Scheme for Surface Exchanges over Land incorporating land surface hydrology (H-TESSEL). It uses version CY45R1 of the IFS.

Currently, ERA5-Land dataset contains only one (9 km) high resolution realisation (HRES). Uncertainty information can currently be used from the reduced resolution ten member ensemble (EDA) of ERA5. The data are available at a sub-daily and monthly frequencies. **For convention and consistency** with the previous ERA-Interim/Land dataset, **the data parameters are labelled as analyses and short (24 hour) forecasts** initialised once daily from analyses at 00 UTC. Accumulation parameters are only available from the forecasts and the convention used in ERA5-Land differs from that for ERA5.

Currently, the data **can only be downloaded on a regular latitude/longitude grid of 0.1°x0.1° via the CDS catalogue**. ECMWF member states with access to the ECMWF Meteorological Archival and Retrieval System (MARS) can also retrieve the data in the native grid.

⚠ **NOTE:** Please, note that since 1st Jan 2020 the new ECMWF Meteorological Interpolation and Regridding interpolation package ([MIR](#)) has been used to interpolate the atmospheric forcing of ERA5 into the ERA5-Land grid. While this change will be unnoticeable for the overwhelming majority of users, locally and under very limited conditions (some areas with high orography, some coastal points) some fields may suffer of a very small discontinuity this day.

### Land Surface Model

H-TESSEL is the land surface model that is the basis of ERA5-Land. The H-TESSEL version used in the production of ERA5-Land corresponds to that of the [IFS model documentation CY45R1](#).

### Data organisation and access

The full ERA5-Land and ERA5-Land-T data are archived in the ECMWF data archive (MARS) and the data have been copied to the Climate Data Store (CDS). ERA5-Land (or recent ERA5-Land-T) data should be downloaded using the CDS catalogue or the CDS API, which can obtain data from the CDS copy or from MARS (Member State users can access the data using MARS directly, in the usual manner). Documentation on how to use the CDS API to download ERA5-Land data can be found [here](#). The installation and downloading steps are similar to those of ERA5.

A couple of downloading examples to extract the data using the CDS API are given below:

➤ [Basic CDS API script example to download hourly snow depth \(in m of water equivalent\) on 1st January 2013 from ERA5-Land data archived in the CDS](#)

```
#!/usr/bin/env python
import cdsapi

c = cdsapi.Client()
c.retrieve(
    'reanalysis-era5-land',
    {
        'format': 'grib',
        'time': [
            '00:00', '01:00', '02:00',
            '03:00', '04:00', '05:00',
            '06:00', '07:00', '08:00',
```

```
'09:00','10:00','11:00',
'12:00','13:00','14:00',
'15:00','16:00','17:00',
'18:00','19:00','20:00',
'21:00','22:00','23:00'
],
'day':'01',
'month':'01',
'year':'2013',
'variable':'snow_depth_water_equivalent',
},
'snow_20130101_era5land.grib')
```

➤ [Basic CDS API script example to download accumulated runoff from 00UTC to 12UTC on 1st January 2013 from ERA5-Land data archived in the CDS](#)

```
#!/usr/bin/env python
import cdsapi

c = cdsapi.Client()

c.retrieve(
    'reanalysis-era5-land',
    {
        'variable':'runoff',
        'year':'2013'
        'month':'01',
        'day':'01',
        'time':'12:00',
        'format':'grib'
    },
    'runoff_00-12_20130101_era5land.grib')
```

➤ [Only for ECMWF member states](#)

The data in the native grid can be accessed from MARS using the keywords *class="I5"* and *expver=0001*. Subdivisions of the data are labelled using the keywords *stream* and *type*. [The keyword 'levtype' should be set to 'sfc' for all the fields in ERA5-Land.](#)

- Stream:**
- oper: HRES sub-daily
  - mnth: HRES synoptic monthly means
  - moda: HRES monthly means of daily means

- Type (for convention):**
- an: analyses
  - fc: forecasts

- Levtype:**
- sfc: surface or single level

**Convention used in MARS:** the date and time of the data is specified with three MARS keywords, *'date'*, *'time'* and *'step'*. For parameters labelled as analyses (see [list of parameters](#)), *step=0* hours so that date and time specify the analysis time. *All forecasts start at 00UTC (time=00 hours)*, and for parameters labelled as forecasts (see [list of parameters](#)), *date* specifies the forecast *start* day and *step* specifies the number of hours since the start of the forecast, with a maximum of *step=24* hours. The combination of *date*, *time* and forecast *step* defines the validity *date/time*. For analyses, the validity *date/time* is equal to the analysis date/time.

**Convention used in the CDS:** *'analyses' are provided if available for a particular parameter, otherwise forecasts are provided.* The date and time of the data is specified using the validity *date/time*, so *step* does not need to be specified. For parameters labelled as forecasts in MARS, steps between 1 and 24 hours have been used to provide data for all the validity times within 24 hours, see Table 0 below.

Table 0: the mapping, for forecasts, between MARS *date*, *time* and *step* and the CDS *date* and *time*

CDS	MARS			CDS	MARS		
date time	date	time	step	date time	date	time	step
date 00	date-1	0	24	date 12	date	0	12
date 01	date	0	1	date 13	date	0	13
date 02	date	0	2	date 14	date	0	14
date 03	date	0	3	date 15	date	0	15
date 04	date	0	4	date 16	date	0	16
date 05	date	0	5	date 17	date	0	17
date 06	date	0	6	date 18	date	0	18
date 07	date	0	7	date 19	date	0	19
date 08	date	0	8	date 20	date	0	20
date 09	date	0	9	date 21	date	0	21
date 10	date	0	10	date 22	date	0	22
date 11	date	0	11	date 23	date	0	23

▾ Spatial grid

The ERA5-Land HRES dataset has been produced at a resolution of 9 km, (~0.08°) and in a (octahedral) reduced Gaussian grid (represented as TCo1279). [Currently, the uncertainty of the fields is to be obtained](#) from the ERA5 EDA dataset, which has a resolution of 62km (~0.56°).

The article ["Model grid box and time step"](#) might be useful.

The data is referenced in the horizontal with respect to the WGS84 ellipse (which defines the major/minor axes) and in the vertical it is referenced to the EGM96 geoid over land but over ocean it is referenced to mean sea level, with the approximation that this is assumed to be coincident with the geoid. For more information on the relationship between mean sea level and the geoid, see for example [Gregory et al. \(2019\)](#).

## Temporal frequency

For sub-daily data for the HRES (*stream=oper*) the parameters labelled as analyses (*type=an*) are available hourly. The once daily short forecasts, run from 00 UTC, also provide data hourly, with steps from 01 to 24. The uncertainty is currently provided by ERA5 EDA fields, which are available every 3 hours for the surface fields.

## Data update frequency

Initial release data, i.e. data with just a few days behind real time, is called **ERA5-Land-T**. Both for the CDS and MARS, daily updates for ERA5-Land-T are available about 5 days behind real time and monthly mean updates are available about 5 days after the end of the month.

*The daily updates for ERA5-Land-T data on the CDS occur at no fixed time during the day.*

For the CDS, ERA5-Land-T data for a month is overwritten by the final ERA5-Land data about two months after the month in question.

For MARS, the final ERA5-Land data are available about two months after the month in question. In addition, the last few months of data are kept online and can be accessed much quicker than older data on tape.

In the event that serious flaws are detected in ERA5-Land-T, the latter could be different to the final consolidated ERA5-Land data. Based on experience with the production of ERA5-Land so far, our expectation is that such an event would occur only when a flaw in the atmospheric forcing (from ERA5) is detected, and the expectation is that the latter occur only on rare occasions.

## Accumulations

Please, note that **the convention for accumulations used in ERA5-Land differs with that for ERA5**. The accumulations in the short forecasts of ERA5-Land (with hourly steps from 01 to 24) are treated the same as those in ERA-Interim or ERA-Interim/Land, i.e., they are accumulated from the beginning of the forecast to the end of the forecast step. For example, runoff at *day=D*, *step=12* will provide runoff accumulated from *day=D*, *time=0* to *day=D*, *time=12*. The maximum accumulation is over 24 hours, i.e., from *day=D*, *time=0* to *day=D+1*, *time=0* (*step=24*).

- HRES: accumulations are from 00 UTC to the hour ending at the forecast step
- For the CDS time, or validity time, of 00 UTC, the accumulations are over the 24 hours ending at 00 UTC i.e. the accumulation is during the previous day
- Synoptic monthly means (*stream=mnth*): accumulations have units of "variable\_units per forecast\_step hours"
- Monthly means of daily means (*stream=moda*): accumulations have units that include "per day", see section [Monthly means](#)

## Monthly means

In addition to the sub-daily data, all ERA5-Land parameters are also available as monthly means. Monthly means are available in two forms:

- Synoptic monthly means**, for each particular time and forecast step (*stream=mnth*) - in the CDS, referred to as "*monthly averaged by hour of day*".
- Monthly means of daily means**, for the month as a whole (*stream=moda*) - in the CDS, referred to as "*monthly averaged*". These monthly means are created from the hourly data for the HRES.

Monthly means for:

- parameters labelled as analyses or instantaneous forecasts are created from data with a valid time in the month, between 00 and 23 UTC on each day of the month.
- accumulations are created from data with a forecast period falling within the month. Monthly means of daily means for accumulations are created from the last forecast step (24) of the forecasts for each day of the month.

The accumulations in monthly means of daily means (*stream=moda*) have units that include "per day". So for accumulations in this stream:

- The hydrological parameters are in units of "m of water equivalent per day" and so they should be multiplied by 1000 to convert to  $\text{kgm}^{-2}\text{day}^{-1}$  or  $\text{mmday}^{-1}$ .
- The energy (turbulent and radiative) and momentum fluxes should be divided by 86400 seconds (24 hours) to convert to the commonly used units of  $\text{Wm}^{-2}$  and  $\text{Nm}^{-2}$ , respectively.

The accumulations in synoptic monthly means (*stream=mnth*) have units that include "variable\_units per forecast\_step hours". So for accumulations in this stream:

- The hydrological parameters are in units of "m of water equivalent per forecast\_step hours" and so they should be multiplied by 1000 to convert to  $\text{kgm}^{-2}$  per forecast\_step hours or  $\text{mm}$  per forecast\_step hours.
- The energy (turbulent and radiative) and momentum fluxes should be divided by  $60 \times 60 \times \text{fc\_step}$  to convert to the units of  $\text{Wm}^{-2}$  and  $\text{Nm}^{-2}$ , respectively.

## Data format

Surface fields in ERA5-Land are encoded either in GRIB1 or GRIB2 format. Tables 1 and 2 indicate the format for all parameters in ERA5-Land. Note that the retrieval of the data in NetCDF format is still **an option available** via the CDS.

The article "[What are GRIB files and how can I read them](#)" might be helpful.

For GRIB format, ERA5-Land-T data can be identified by the key `expver=0005` in the GRIB header. Consolidated ERA5-Land data is identified by the key `expver=0001`.

For netCDF data requests which return just ERA5-Land or just ERA5-Land-T data, there is no means of differentiating between ERA5-Land and ERA5-Land-T data in the resulting netCDF files.

For netCDF data requests which return a mixture of ERA5-Land and ERA5-Land-T data, the origin of the variables (1 or 5) will be identifiable in the resulting netCDF files. See this [link](#) for more details applied to ERA5 data.

## Parameter listings

Tables 1 and 2 below describe the surface parameters available in ERA5-Land (*levtype=sfc*). Information on all ECMWF parameters is available from the [ECMWF parameter database](#).

For the sake of completeness, most of the **forcing fields used to run ERA5-Land are included** in the catalogue. Note, however, that **these fields have purely been interpolated to the ERA5-Land grid and they are not obtained by running the land surface model (i.e., a purely linear interpolation based on a triangular mesh)**. They are included in Table 1 and Table 2 below under the column "Used as forcing field".

**Auxiliary land invariant parameters** are attached here below, already interpolated to a regular lat/lon grid of  $0.1^\circ \times 0.1^\circ$ . Relevant information about how to use/interpret these fields are in chapter 8 of <https://www.ecmwf.int/en/elibrary/18714-ifs-documentation-cy45r1-part-iv-physical-processes>, and plots of these fields are in chapter 11.

Parameters described as "instantaneous" in Table 2 are [valid at the specified time](#).

Note that in the tables below, "an" and "fc" is just a label used for convention to archive the data in MARS.

▼ Table 1: surface parameters: **invariants (in time)**

name	download link	units	shortName	paramId	GRIB1	GRIB2	netCDF4
Geopotential	<a href="#">Geopotential</a> (GRIB version 1) <a href="#">Geopotential</a> (GRIB version 2) <a href="#">Geopotential</a> (netCDF4)	m**2 s**-2	z	129	x	x	x
Lake cover	<a href="#">Lake cover</a> (GRIB version 2) <a href="#">Lake cover</a> (netCDF4)	(0-1)	cl	26		x	x
Lake total depth	<a href="#">Lake total depth</a> (GRIB version 2) <a href="#">Lake total depth</a> (netCDF4)	m	dl	228007		x	x
Land-sea-mask	<a href="#">Land-sea-mask</a> (GRIB version 2) <a href="#">Land-sea mask</a> (netCDF4)	(0-1)	lsm	172		x	x
Low vegetation cover	<a href="#">Low vegetation cover</a> (GRIB version 2) <a href="#">Low vegetation cover</a> (netCDF4)	(0 - 1)	cvl	27		x	x
High vegetation cover	<a href="#">High vegetation cover</a> (GRIB version 2) <a href="#">High vegetation cover</a> (netCDF4)	(0 - 1)	cvh	28		x	x
Glacier mask	<a href="#">Glacier mask</a> (GRIB version 2) <a href="#">Glacier mask</a> (netCDF4)	Proportion	glm	260294		x	x
Soil type	<a href="#">Soil type</a> (GRIB version 2) <a href="#">Soil type</a> (netCDF4)	~	slt	43		x	x
Type of low vegetation	<a href="#">Type of low vegetation</a> (GRIB version 1) <a href="#">Type of low vegetation</a> (netCDF4)	~	tlv	29	x		x
Type of high vegetation	<a href="#">Type of high vegetation</a> (GRIB version 1) <a href="#">Type of high vegetation</a> (netCDF4)	~	tvh	30	x		x

▼ Table 2: stream=oper/mnth/moda, levtype=sfc: surface parameters: **instantaneous**

	name	units	Variable name in CDS	shortName	paramId	an	fc	GRIB1	GRIB2	Used as forcing field
1	<a href="#">Lake mix-layer temperature</a>	K	lake_mix_layer_temperature	lmlt	228008	x		x		
2	<a href="#">Lake mix-layer depth</a>	m	lake_mix_layer_depth	lml d	228009	x		x		
3	<a href="#">Lake bottom temperature</a>	K	lake_bottom_temperature	lblt	228010	x		x		
4	<a href="#">Lake total layer temperature</a>	K	lake_total_layer_temperature	ltlt	228011	x		x		
5	<a href="#">Lake shape factor</a>	dimensionless	lake_shape_factor	lshf	228012	x		x		
6	<a href="#">Lake ice temperature</a>	K	lake_ice_temperature	lic t	228013	x		x		
7	<a href="#">Lake ice depth</a>	m	lake_ice_depth	lic d	228014	x		x		
8	<a href="#">Snow cover</a>	%	snow_cover	snowc	260038		x		x	
9	<a href="#">Snow depth</a>	m	snow_depth	sde	3066		x		x	

10	<a href="#">Snow albedo</a>	(0 - 1)	snow_albedo	asn	32	x		x		
11	<a href="#">Snow density</a>	kg m**3	snow_density	rsn	33	x		x		
12	<a href="#">Volumetric soil water layer 1<sup>1</sup></a>	m**3 m**3	volumetric_soil_water_layer_1	swvl1	39	x		x		
13	<a href="#">Volumetric soil water layer 2<sup>1</sup></a>	m**3 m**3	volumetric_soil_water_layer_2	swvl2	40	x		x		
14	<a href="#">Volumetric soil water layer 3<sup>1</sup></a>	m**3 m**3	volumetric_soil_water_layer_3	swvl3	41	x		x		
15	<a href="#">Volumetric soil water layer 4<sup>1</sup></a>	m**3 m**3	volumetric_soil_water_layer_4	swvl4	42	x		x		
16	<a href="#">Leaf area index, low vegetation<sup>2</sup></a>	m**2 m**2	leaf_area_index_low_vegetation	lai_lv	66		x	x		
17	<a href="#">Leaf area index, high vegetation<sup>2</sup></a>	m**2 m**2	leaf_area_index_high_vegetation	lai_hv	67		x	x		
18	<a href="#">Surface pressure</a>	Pa	surface_pressure	sp	134		x	x		x
19	<a href="#">Soil temperature level 1<sup>1</sup></a>	K	soil_temperature_level_1	stl1	139	x		x		
20	<a href="#">Snow depth water equivalent</a>	m of water equivalent	snow_depth_water_equivalent	sd	141	x		x		
21	<a href="#">10 metre U wind component</a>	m s**-1	10m_u_component_of_wind	u10	165		x	x		x
22	<a href="#">10 metre V wind component</a>	m s**-1	10m_v_component_of_wind	v10	166		x	x		x
23	<a href="#">2 metre temperature</a>	K	2m_temperature	2t	167		x	x		
24	<a href="#">2 metre dewpoint temperature</a>	K	2m_dewpoint_temperature	2d	168		x	x		
25	<a href="#">Soil temperature level 2<sup>1</sup></a>	K	soil_temperature_level_2	stl2	170	x		x		
26	<a href="#">Soil temperature level 3<sup>1</sup></a>	K	soil_temperature_level_3	stl3	183	x		x		
27	<a href="#">Skin reservoir content</a>	m of water equivalent	skin_reservoir_content	src	198	x				
28	<a href="#">Skin temperature</a>	K	skin_temperature	skt	235	x		x		
29	<a href="#">Soil temperature level 4<sup>1</sup></a>	K	soil_temperature_level_4	stl4	236	x		x		
30	<a href="#">Temperature of snow layer</a>	K	temperature_of_snow_layer	tsn	238	x		x		
31	<a href="#">Forecast albedo</a>	(0 - 1)	forecast_albedo	fai	243		x	x		

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► [Soil levels](#)

Layer	Range
Layer 1	0 - 7 cm
Layer 2	7 - 28 cm
Layer 3	28 - 100 cm
Layer 4	100 - 289 cm

<sup>2</sup> **Leaf Area Index (LAI)** parameters are based on a monthly climatology as explained [IFS model documentation CY45R1](#). So the users will only see monthly variability, but not inter-annual variability.

Table 3: stream=oper/mnth/moda, levtype=sfc: surface parameters: [accumulations](#)

	name	units	Variable name in CDS	shortName	paramId	an	fc	GRIB1	GRIB2	Used as forcing field
1	<a href="#">Surface runoff</a>	m	surface_runoff	sro	8		x	x		
2	<a href="#">Sub-surface runoff</a>	m	sub_surface_runoff	ssro	9		x	x		
3	<a href="#">Snow evaporation</a>	m of water equivalent	snow_evaporation	es	44		x	x		
4	<a href="#">Snowmelt</a>	m of water equivalent	snowmelt	smlt	45		x	x		
5	<a href="#">Snowfall</a>	m of water equivalent	snowfall	sf	144		x	x		x
6	<a href="#">Surface sensible heat flux</a>	J m <sup>-2</sup>	surface_sensible_heat_flux	sshf	146		x	x		
7	<a href="#">Surface latent heat flux</a>	J m <sup>-2</sup>	surface_latent_heat_flux	slhf	147		x	x		
8	<a href="#">Surface solar radiation downwards</a>	J m <sup>-2</sup>	surface_solar_radiation_downwards	ssrd	169		x	x		x
9	<a href="#">Surface thermal radiation downwards</a>	J m <sup>-2</sup>	surface_thermal_radiation_downwards	strd	175		x	x		x
10	<a href="#">Surface net solar radiation</a>	J m <sup>-2</sup>	surface_net_solar_radiation	ssr	176		x	x		x
11	<a href="#">Surface net thermal radiation</a>	J m <sup>-2</sup>	surface_net_thermal_radiation	str	177		x	x		x
12	<a href="#">Total Evaporation</a>	m of water equivalent	total_evaporation	e	182		x	x		
13	<a href="#">Runoff</a>	m	runoff	ro	205		x	x		
14	<a href="#">Total precipitation</a>	m	total_precipitation	tp	228		x	x		x
15	<a href="#">Evaporation from the top of canopy</a>	m of water equivalent	evaporation_from_the_top_of_canopy	evatc	228100		x		x	
16	<a href="#">Evaporation from bare soil</a>	m of water equivalent	evaporation_from_bare_soil	evabs	228101		x		x	
17	<a href="#">Evaporation from open water surfaces excluding oceans</a>	m of water equivalent	evaporation_from_open_water_surfaces_excluding_oceans	evaow	228102		x		x	
18	<a href="#">Evaporation from vegetation transpiration</a>	m of water equivalent	evaporation_from_vegetation_transpiration	evavt	228103		x		x	
19	<a href="#">Potential evaporation</a>	m	potential_evaporation	pev	228251		x	x		

Accumulations are described in section [ERA5-Land: data documentation#accumulations](#). The accumulations in monthly means (stream=moda/mnth) are described in section [monthly means](#)

## Guidelines

### 1. [Actual and potential evapotranspiration](#)

**Actual evapotranspiration** in the ERA5-Land datasets is called "Total Evaporation" (param ID 182) and is the sum of the following four evaporation components:

- [Evaporation from bare soil](#)
- [Evaporation from open water surfaces excluding oceans](#)
- [Evaporation from the top of canopy](#)
- [Evaporation from vegetation transpiration](#)

For the ERA5-Land datasets, actual evapotranspiration and it's four components can be downloaded from the C3S Climate Data Store (CDS) under the category heading "Evaporation and Runoff".

For details about the computation of actual evapotranspiration, please see Chapter 8 of Part IV : Physical processes, of the IFS documentation:

[ERA5-Land IFS cycle 45r1](#)

The **potential evapotranspiration** in the ERA5-Land CDS dataset is given by the parameter [potential evaporation \(pev\)](#).

Pev data can be downloaded from the CDS under the category heading "Evaporation and Runoff", in the "Download data" tab for the ERA5-Land datasets.

⚠ The definitions of **potential** and **reference evapotranspiration** may vary according to the scientific application and can have the same definition in some cases. Users should therefore ensure that the definition of this parameter is suitable for their application.

Please note that to give more flexibility to users, PEV in ERA5 and ERA5Land are not computed in the same way:

- ERA5: the definition of **PEV in ERA5** is computed for **agricultural** land as if it is well watered (**no soil moisture stress**) and assuming that the atmosphere is not affected by this artificial surface condition.
- ERA5Land: the definition of **PEV in ERA5Land** is computed as an open water evaporation (**Pan evaporation**) and assuming that the atmosphere is not affected by this artificial surface condition.

⚠ Please note that based on ERA5-Land atmospheric forcing, other independent (offline) methods such as "Priesley-Taylor<sup>1</sup> (1972) , Schmidt<sup>2</sup> (1915) or de Bruin<sup>3</sup> (2000)" can also be used to estimate Potential evapotranspiration.

<sup>1</sup>PRIESTLEY, C. H. B., & TAYLOR, R. J. (1972). On the Assessment of Surface Heat Flux and Evaporation Using Large-Scale Parameters, *Monthly Weather Review*, 100(2), 81-92. Retrieved Aug 27, 2021, from [https://journals.ametsoc.org/view/journals/mwre/100/2/1520-0493\\_1972\\_100\\_0081\\_otaosh\\_2\\_3\\_co\\_2.xml](https://journals.ametsoc.org/view/journals/mwre/100/2/1520-0493_1972_100_0081_otaosh_2_3_co_2.xml)

<sup>2</sup>Schmidt, W., 1915: Strahlung und Verdunstung an freien Wasserflächen; ein Beitrag zum Wärmehaushalt des Weltmeers und zum Wasserhaushalt der Erde (Radiation and evaporation over open water surfaces; a contribution to the heat budget of the world ocean and to the water budget of the earth). *Ann. Hydro. Maritimen Meteor.*, **43**, 111–124, 169–178.

<sup>3</sup>de Bruin, H. A. R., , and Stricker J. N. M. , 2000: Evaporation of grass under non-restricted soil moisture conditions. *Hydrol. Sci. J.*, **45**, 391–406, doi:10.1080/02626660009492337.

## 2. > How to use lake-related fields

Independently whether a model grid point is over a lake or not, the IFS computes lake variables all over the globe, at each grid-box. This is to ease output field aggregation at diverse model resolutions and to have a warm start of the model with shorter spin-up time if lake cover is upgraded, i.e., it is still a decent lake initial condition if lake location are updated or a new lake is added operationally. Lake depths (input parameter for our lake parametrization) are specified for each grid-box either with in-situ values or with a default 25 m value; over ocean we use ocean bathymetry. Worth to mention that the later default values will be changed soon (extra information in [this HESS reference](#)). The computed lake variable values are not taken into account in the total grid-box flux calculations if lake is not present in the grid-box.

The lake fields provided in ERA5-Land can be used in combination with the lake location. The latter in the model is determined by lake cover field ([parameter name CL](#), in fraction: 0 - grid-box has no lakes, 1 - grid-box is fully covered with lake/s). Lake depths are presented in [the field DL](#) (in meters).

The ECMWF model also contains an ice module, a snow module and a bottom sediments module. The present setup of the IFS is running with no bottom sediment and snow modules (snow accumulation over ice is not allowed and snow parameters are used only for albedo purposes). In the implementation in the IFS lake ice can be fractional within a grid-box with inland water (10 cm of ice means 100 % of a grid-box or tile is covered with ice; 0 cm of ice means 100 % of the grid-box is covered by water; in between a linear interpolation is applied) ([Manrique-Sunen et al., 2013](#)). At present, the water balance equation is not included for lakes and the lake depth and surface area are kept constant in time ([IFS Documentation, 2017, chapter 8 and 11](#) ). Lake parametrization also requires the lake fraction CL, lake depth DL (preferably bathymetry), and lake initial conditions. DL is the most important external parameter that uses the lake parametrization.

## > Known issues

1. ERA5-Land forecast parameters are missing for the validity time of 1st January 1950 00 UTC.

### 2. > Uncertainty fields

As it was done for ERA5, the original plan for ERA5-Land was to provide an estimate of the uncertainty fields based on a dedicated 10-member ensemble run. The latter generated an ensemble of forcing fields that should, in principle, reproduce the space of uncertainty for the land surface fields. The first experiments demonstrated that the spread of the ensemble was clearly under dispersive, i.e. the uncertainty was unrealistically low. A reason for this is the low spread shown by the ensemble of ERA5 forcing fields.

As a result of these experiments we took the decision of not providing the uncertainty fields of ERA5-Land. The opposite would have assigned, for instance, unrealistically high confidence to ERA5-land fields in a data assimilation experiment.

Our recommendation is, for the time being, to use the uncertainty estimate of the corresponding ERA5 field, which should provide a second order approximation to the estimate of the real uncertainty. Future experiments will also perturb, among other, key land surface model parameters, therefore providing a more realistic spread of the ERA5-Land ensemble surface fields.

### 3. > Swapped value of the components of the total evapotranspiration

a. Three components of the total evapotranspiration have values swapped as follows:

- variable **"Evaporation from bare soil"** ([mars parameter code 228101 \(evabs\)](#)) has the values corresponding to the **"Evaporation from vegetation transpiration"** ([mars parameter 228103 \(evavt\)](#)),
- variable **"Evaporation from open water surfaces excluding oceans"** ([mars parameter code 228102 \(evaow\)](#)) has the values corresponding to the **"Evaporation from bare soil"** ([mars parameter code 228101 \(evabs\)](#)),
- variable **"Evaporation from vegetation transpiration"** ([mars parameter code 228103 \(evavt\)](#)) has the values corresponding to the **"Evaporation from open water surfaces excluding oceans"** ([mars parameter code 228102 \(evaow\)](#)).

### 4. > Low values of snow cover and snow depth on the eastern side of the Antarctic ice sheet

Low values of snow cover and snow depth were found on the eastern side of the Antarctic ice sheet, as shown in Fig. 1. The issue is due to the application of an old glacier mask to the Antarctica, which excludes the patch shown in the figure as glacier. Inaccuracies in the glacier mask are due to errors in satellite measurements datasets. While, due to the lower horizontal resolution, in ERA5 this ice sheet part is a sea point, in ERA5-Land the area is categorised as land without an initial ice mass. Since the initialization doesn't consider a glacier there (estimated at a constant 10 m of snow water equivalent), the low amount of precipitation along with potential excess of sublimation makes them to obtain unrealistic low numbers there.

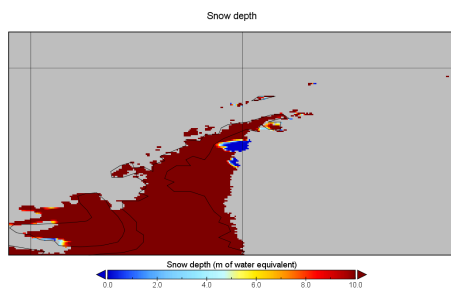


Fig 1: ERA-Land Snow depth (m of water equivalent) on 01-01-2015 eastern side of the Antarctic ice sheet.

### 5. > Limited impact from sub-optimal tropical cyclones in the forcing from the ERA5 preliminary dataset for 1950-1978.

From 1950-1978 ERA5-Land was forced by the preliminary ERA5 back extension which has a [sub-optimal representation for a number of tropical cyclones](#).

The over-estimation of a number of tropical cyclones for this period affects some products over the oceans in the vicinity of tropical cyclone tracks. Over land much smaller impact is expected, and therefore, the effect on the ERA5-Land product from 1950-1978 is more limited.

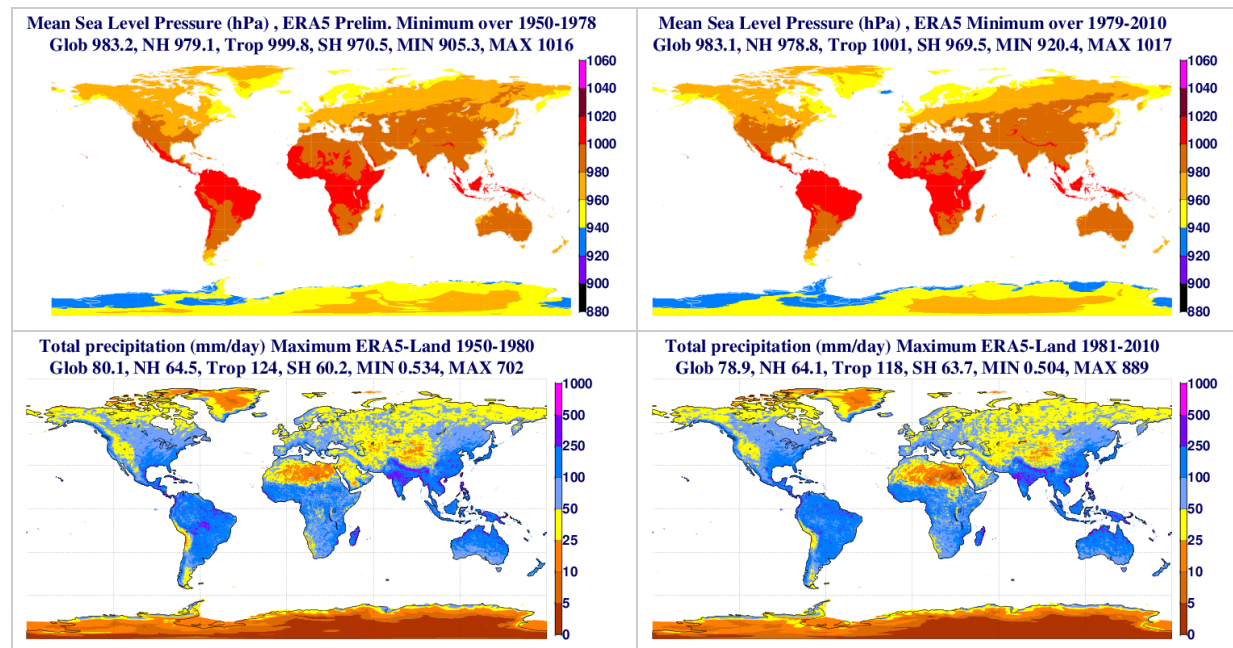
This is supported by the figure below that plots, for each location, the minimum pressure from the ERA5 forcing (top panels) and the maximum daily accumulated total precipitation for ERA5-Land (lower panels) for the (preliminary) back extension (left panels) and for the period from the late 1970s to 2010 inclusive (right panels). Note that these show the most extreme situations, i.e., the absolute extremes in



the about 30-year periods that were considered in each plot. Less extreme statistics, like 99, 95 (etc.) percentiles or mean distributions will show a much smaller impact of tropical cyclones.

From these panels it is seen that for the forcing from ERA5 (top panels), in general, local minimum pressure is similar between 1950-1978 and 1979-2010. There are of course sampling differences between the two, each about 30-year, periods. Large differences that are likely related to anomalously strong tropical cyclones are very localized, such as for some areas over North Australia, East Madagascar, Philippines and Northeast China. Note again that these affect a few cases only in the 29-year dataset.

The effect on the ERA5-Land precipitation is shown in the lower panels. Even for these extremes it is difficult to pin-point locations that could be affected by anomalous tropical cyclones.



Caption: locally minimum of 6-hourly pressure for ERA5 forcing data (top panels) and maximum daily total precipitation (lower panels) over the indicated period of time for the back extension (left panels) and for later periods (right panels). Numbers represent the averages for the locally extreme values over the indicated areas.

#### 6. Definition of Potential Evaporation (PEV) modified

Note that on 18-11-2021 we modified the definition of Potential Evaporation (PEV) provided in the CDS catalogue entry for both, the hourly and the monthly fields. The reason is that until this date the definition of PEV was similar to that of the same field provided by ERA5, whereas in reality they are computed differently:

- **PEV in ERA5** is computed for **agricultural** land as if it is well watered (**no soil moisture stress**) and assuming that the atmosphere is not affected by this artificial surface condition.
- **PEV in ERA5-Land** is computed as an open water evaporation (**Pan evaporation**) and assuming that the atmosphere is not affected by this artificial surface condition.

#### 7. Incorrect values of monthly averaged reanalysis of accumulated fields from September 2022 to February 2024

An issue with the **ERA5-Land monthly averaged data from 1950 to present** dataset was identified in January 2024 **on both CDS discs and MARS tapes**. It affects the following part of the dataset:

**Product:** Monthly averaged reanalysis

**Time period:** from September 2022 to February 2024

**Area:** Global

**Variables:** all accumulated variables (please refer to [Table 3 in ERA5-Land documentation](#))

Incorrect data for period September 2022 to February 2024 is no longer available to download using the interactive CDS [Download data form](#) over the web, but remains accessible for the time being via CDS API or direct MARS access.

**Incorrect data from September 2022 to February 2024 will not be replaced on CDS discs nor MARS tapes. Instead users can recover the same (and correct) data using the product monthly averaged reanalysis by hour of day at 00:00.**

A fix was implemented for ERA5-Land monthly averaged data stored on CDS discs in time for the release of March 2024 monthly averaged data (i.e. from March 2024 onwards).

### How to cite the ERA5-Land dataset

In addition to the terms and conditions of the license(s), users **must**:

- cite the CDS catalogue entry;
- provide clear and visible attribution to the Copernicus programme and attribute each data product used;

**Step 1:** Check the [licence to use Copernicus Products](#) for attribution/reference clause.

**Step 2:** Cite the CDS catalogue entry (as traceable source of data).

**Step 3:** Provide clear and visible attribution to the Copernicus programme and attribute each data product used (to accredit the creators of the data). Throughout the content of your publication, the dataset used is referred to as Author (YYYY).

The 3-steps procedure above is illustrated with this example:

[Use Case 1: ERA5-Land hourly data from 1950 to present](#)

For complete details, please refer to [How to acknowledge and cite a Climate Data Store \(CDS\) catalogue entry and the data published as part of it](#).

### Reference articles

J. Muñoz-Sabater, Dutra, E., Agustí-Panareda, A., Albergel, C., Arduini, G., Balsamo, G., Boussetta, S., Choulga, M., Harrigan, S., Hersbach, H., Martens, B., Miralles, D. G., Piles, M., Rodríguez-Fernández, N. J., Zsoter, E., Buontempo, C., and Thépaut, J.-N.: ERA5-Land: A state-of-the-art global reanalysis dataset for land applications, Earth Syst. Sci. Data, 13, 4349–4383, 2021. <https://doi.org/10.5194/essd-13-4349-2021>.

[ERA5-Land news](#)

Further ERA5-Land references and related information are available from the [ECMWF website](#).



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[ERA5: data documentation](#)

[Essential Climate Variables for assessment of climate variability from 1979 to present: Product user guide](#)

[The family of ERA5 datasets](#)

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[ERA5: compute pressure and geopotential on model levels, geopotential height and geometric height](#)

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