Funded by the European Union

Coordinated by ECMWF

TIME-VARYING LAKE SURFACE COVER FOR REANALYSIS APPLICATION

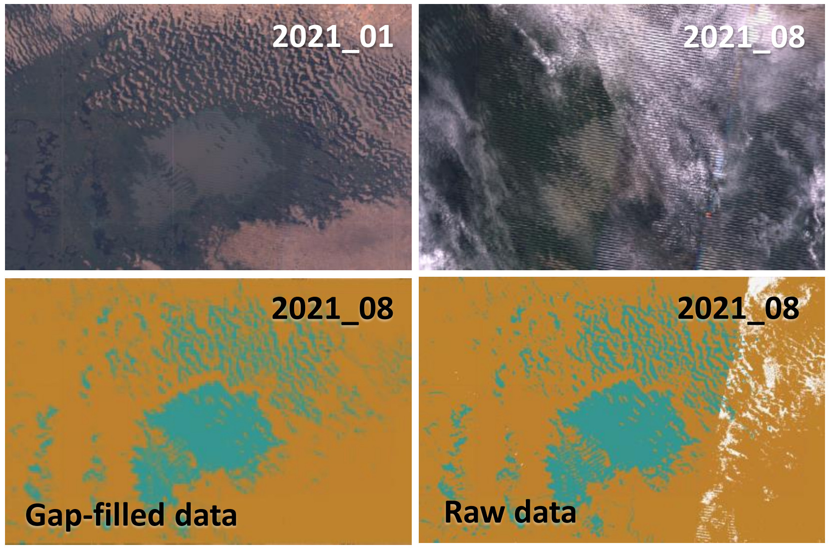
One perfect rule with 99 exceptions

Margarita Choulga*, Gianpaolo Balsamo, Souhail Boussetta, Pedro Maciel, David Fairbairn, Tom Kimpson, Ekaterina Kurzeneva, Elena Shevnina, Patricia de Rosnay

* European Centre for Medium-Range Weather Forecasts (ECMWF)

CopERnIcus climate change Service Evolution - CERISE

USGS Landsat 7 Collection 2 Tier 1 Raw Scenes



Lake Chad, west-central Africa

ECMWF · Norwegian Meteorological Institute · SMHI · Deutscher Wetterdienst DWD Wetter und Klima aus einer Hand · cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici · BSC Barcelona Supercomputing Center Centro Nacional de Supercomputación · METEO FRANCE · The Danish Meteorological Institute · Estellus · IPMA · NILU · Met Office

Funded by the European Union

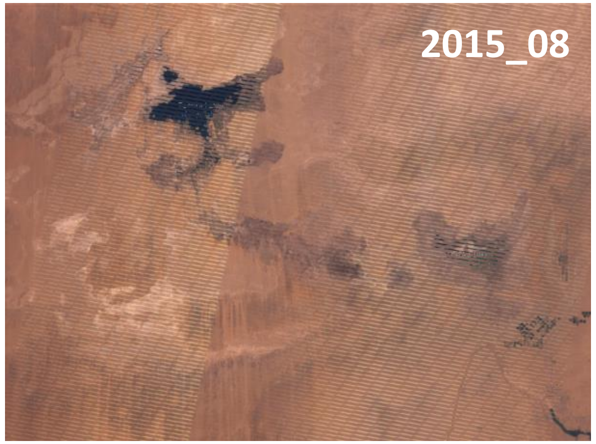
Background

Need for time-varying surface information

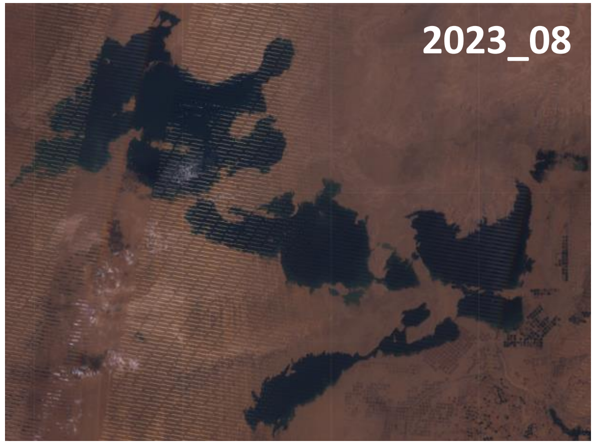
The Toshka Lakes (Egypt) initially **formed from** massive flash **floods** and river floods in Ethiopia in **1998**, which caused floodwaters to flow down the Nile River.

Images on the right are from USGS **Landsat 7** Collection 2 Tier 1 Raw Scenes.

Agricultural activity in the Toshka Lakes region rose rapidly in the 2000s, but **soon** the **water levels** of the lakes **declined** and **became empty** again by **2018**.



The regrowth of the Toshka lakes from 2018 to 2023 due to heavy rainfall in Sudan and South Sudan in the summer of 2019 and major flooding events in Sudan in 2020, 2021, and 2022.



Kimpson, T., Choulga, M., Chantry, M., Balsamo, G., Boussetta, S., Dueben, P., and Palmer, T.: Deep learning for quality control of surface physiographic fields using satellite Earth observations, Hydrol. Earth Syst. Sci., 27, 4661–4685, **https://doi.org/10.5194/hess-27-4661-2023**, 2023.

Funded by the European Union

Input data

Reliable, global, consistent in time, high horizontal resolution

- JRC Global Surface Water Explorer (JRC **GSWE**) dataset, EPSG:4326 **30 m resolution 1984-2021**
  - ‘***transition***’ – 10 **water classes** (e.g. permanent, seasonal, etc.);
  - ‘***monthlyHistory***’ – **monthly surface classification** (i.e. water, notWater, noData).
- (additional) **Copernicus** DEM **GLO30** dataset, EPSG:4326 **30 m resolution 2015**
  - ***‘elevation’*** – digital surface model values, meters
  - ‘***waterBodyMask***’ – 4 surface classes (i.e. not water, ocean, lake, river);
- (additional) numerous **regional glacier** datasets, different grids/ resolution (**15-100 m**)/ period/ format
  - i.e. British Antarctic Survey, QUANTARCTICA, GIMP project, QGREENLAND, Norwegian Institute, Icelandic Metservice.

Methodology

CERISE

Reproducible, understandable, automated, reliable, adaptable

- **Determine grid cell type** (i.e. *water*, *notWater*, *noData*) based on the dominant type for
  - the whole period,
  - each month of the whole period,
  - every 10 years of the whole period;
- **Fill *noData*** grid cell type by combining previously obtained information;
- **Calculate permanent water** distribution **per 10-year** period and
  - **correct regionally in space** over glaciers, islands, and far north areas,
  - **correct regionally in time** for years prior to available data;
- **Calculate seasonal monthly water** distribution **per 10-year** period and follow the **same procedure as for permanent** water;
- **Separate water** into **inland** and **ocean**;
- **Reduce resolution** from 30 m to 1 km.

Funded by the European Union

Results

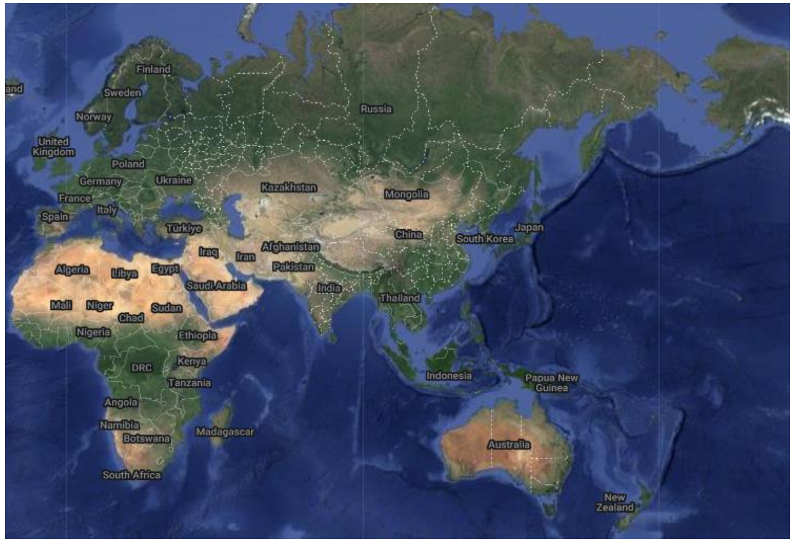
- **Global seasonally varying water** distribution maps were generated **based** on high horizontal (**30m**) and temporal (**month**) resolution **satellite data** for the past **50 years** and some high-fidelity auxiliary data (e.g. coastline shapefiles, elevation datasets).
- Maps generated for **1992-2021** are **fully independent** and are purely based on satellite data.
- Earlier (**1962-1991**) maps have in general the **1992-2001 period as a baseline** and are **updated** only **regionally** - based on available reliable satellite information or historic records (i.e. maps, verbal description) with supplementary elevation data criteria.
- The **regional** map **corrections** and/or updates were implemented:
  - (i) regions with frozen 2012-2021 distribution;
  - (ii) regions with 1982-1991 baseline distribution;
  - (iii) regions with **altered baseline** distribution **to match reality**;
  - (iv) regions with **updated baseline** distribution **to match historical information**.
- **Generated** maps are grouped **per 10-year period**, each period has one permanent water map and **twelve monthly maps** (i.e. permanent water + monthly delta).
- The **first** available period is **1962-1972** due to booming water-related anthropogenic activities, i.e. building of large reservoirs and irrigation channels, reverting rivers, etc. It is **assumed** that for the earlier periods (**1925-1961**) maps for **1962-1971 can be used** (due to decreased availability of situ data and its quality to make any assumptions/ calculations or verification).

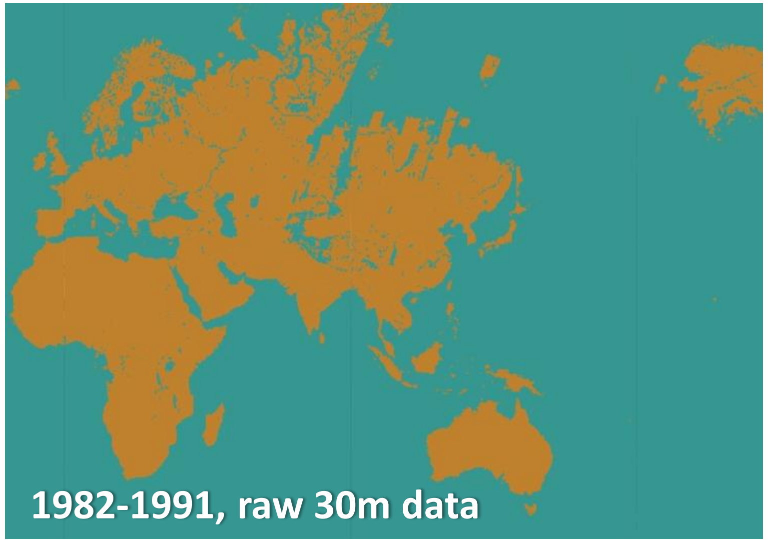
Interesting notes

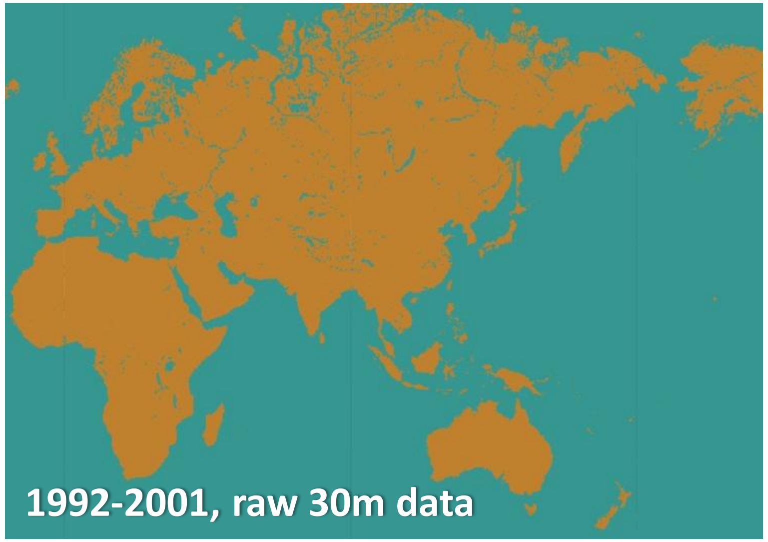
Funded by the European Union

Inland water distribution explicitly **omits melting glacier tops**. The plots below show Ireland’s glacier region.

Inland water distribution for **1982-1991** is **based on 1992-2001** data **with regional updates** only (same technique is used **for years prior** to 1982) - in some regions number of valid observations before 1992 is significantly lower → unpredictable results. The plots below show submerging of West Russia and New Zealand in 1982-1991.



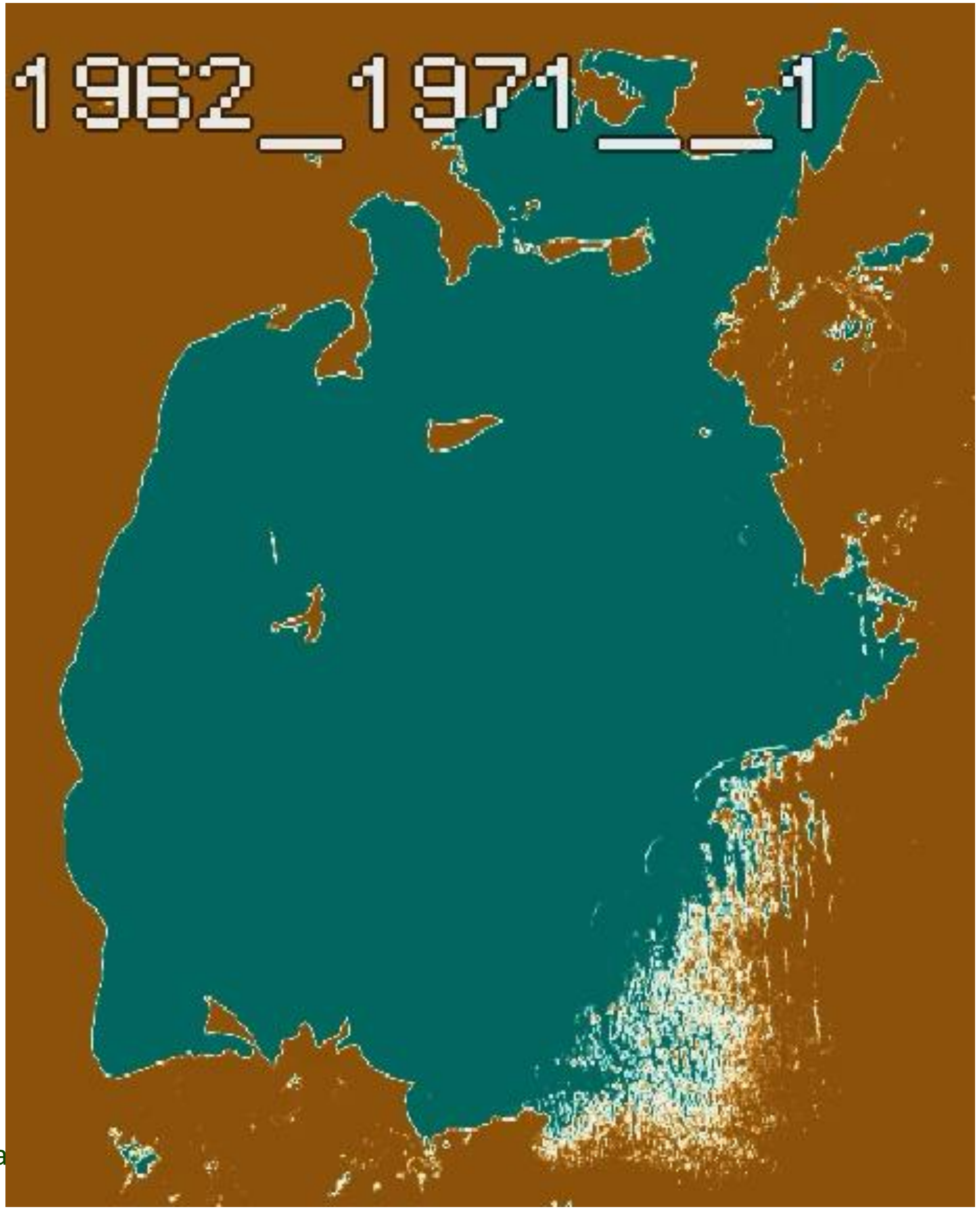




Aral Sea

Generated 1km time-varying lake cover 1962-2021

Historical drying trends & seasonality are well captured. Current maps well represent the current state due to the stabilisation of the area's water distribution.

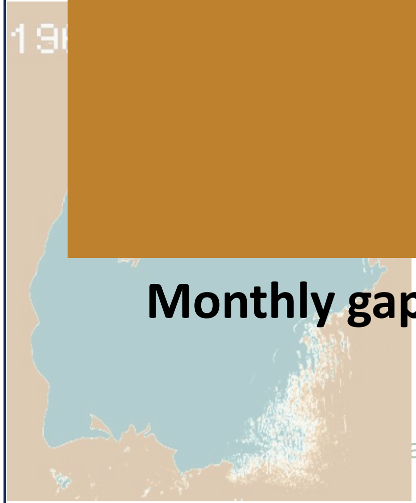


Toshka Lakes

Historical formation and seasonality are well captured.
Current maps lack up-to-date information.

Aral Sea

Generated 1km time-varying lake cover 1962-2021



Monthly gap-filled water fraction, 30 m resolution

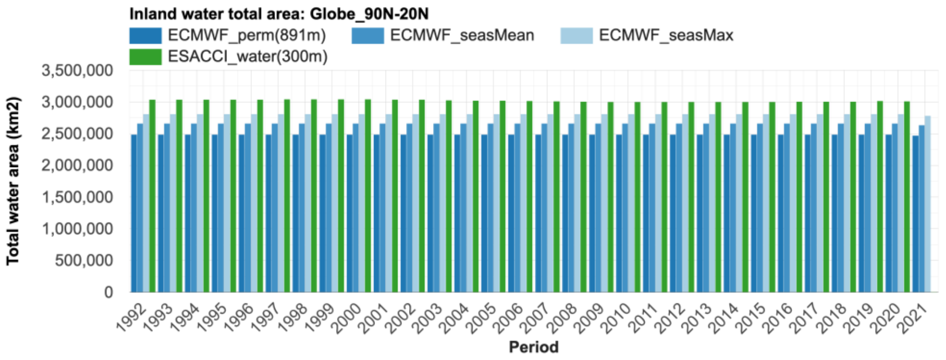
Toshka Lakes

Historical formation and seasonality are well captured.

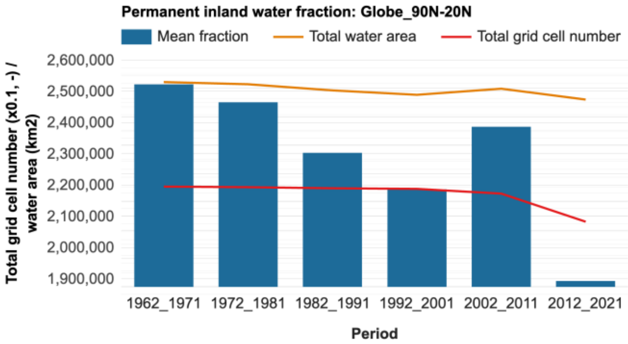
Current maps lack up-to-date information.

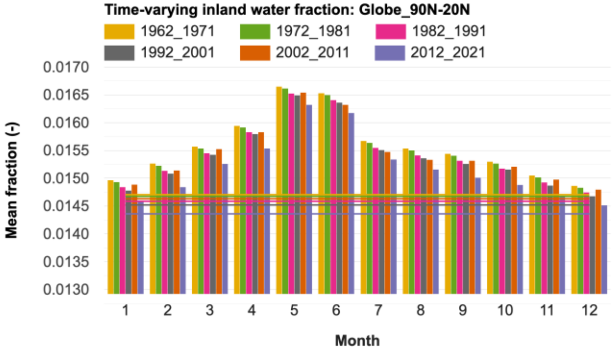
Funded by the European Union

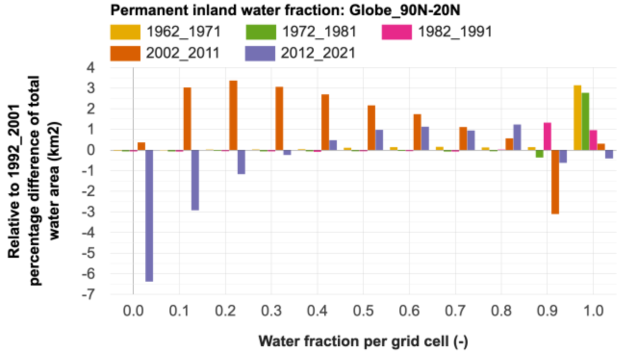
Comparison:
inland water at 1km
Globe 90°N-20°N

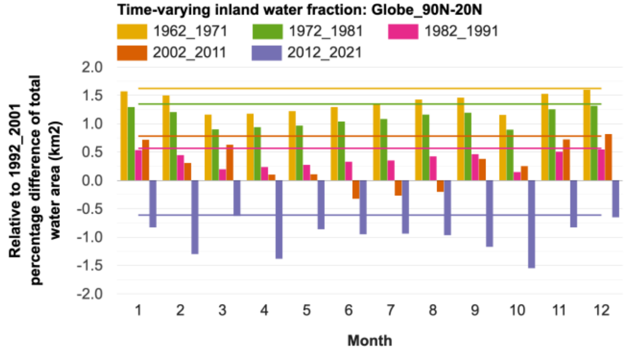


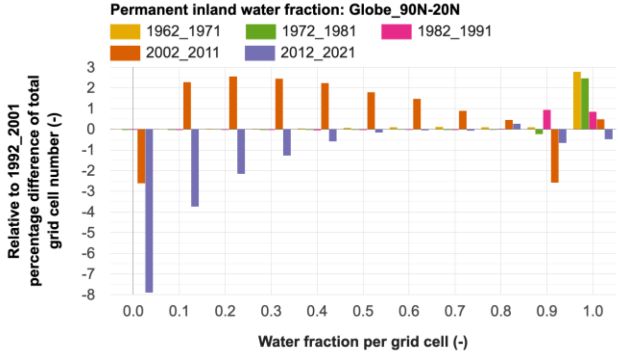
- The inland water cover changes from decade to decade (*second-row left-column plot*);
- In general, total water area and total water grid cell number curves follow each other from decade to decade (*second-row left-column plot*),
  yet in 2012-2021 number of grid cells with small water fractions decreased (*fourth-row left-column plot*),
  and total water area over those grid cells decreased as well (*third-row left-column plot*),
  nevertheless, it had a weak impact on the total water surface area (*second-row left-column plot*);
- The mean water fraction and total water area have yearly cycles (*second- and third-row right-column plots*);
- Data comparison (*first-row plot*) with ESA CCI shows consistently less water than in ESA CCI – most probable reason: difference in nominal data resolution (*i.e. 30 m vs 300 m for ESA CCI*) and difference in water type, where data captures monthly variations but best over the decade, and ESA CCI captures maximum water extent of the specific year (*ocean filtered with specially generated constant in time mask for 2015*).

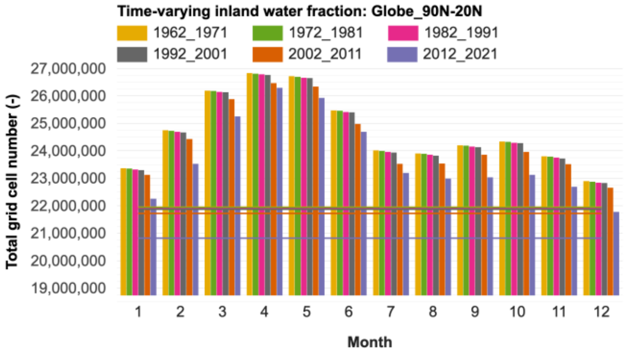










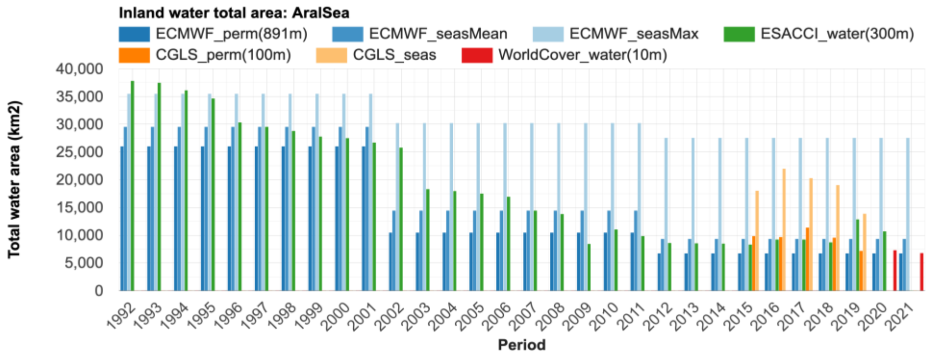


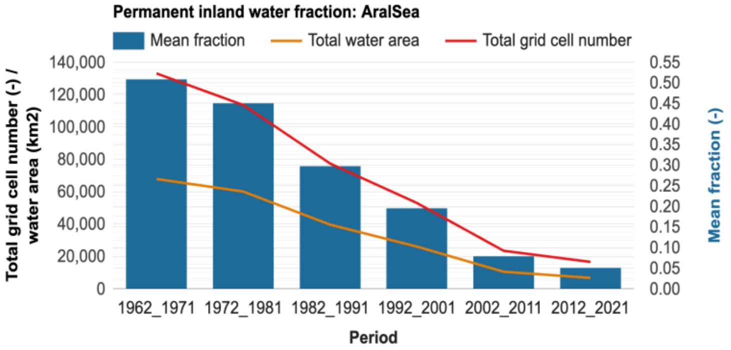
CopERnIcus climate change Service Evolution - CERISE

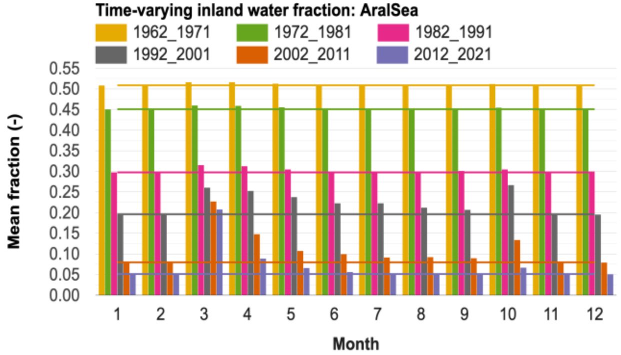
Funded by the European Union

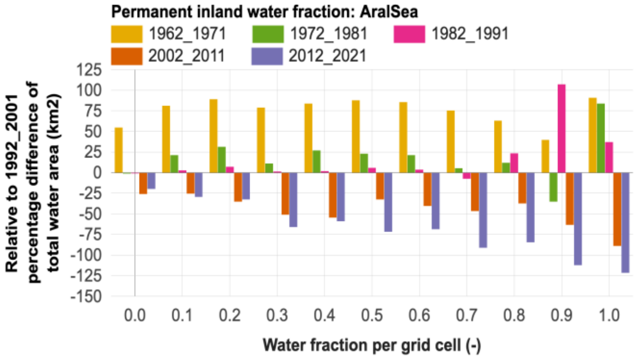
Comparison:
inland water at 1km
Aral Sea

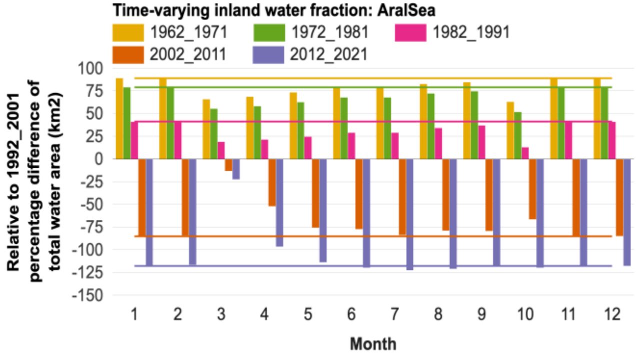
- Historical **drying trends and seasonality** of the Aral Sea are **well** captured (*second-row left and right-column plots*);
- Current maps **well represent** the **current state** due to the stabilisation of the area's water distribution;
- Data comparison (*first-row plot*) shows **very good correlation** with **yearly information** of:
  - ESA CCI (**300 m** nominal resolution);
  - Copernicus CGLS (**100 m** nominal resolution);
  - ESA WorldCover (**10 m** nominal resolution).

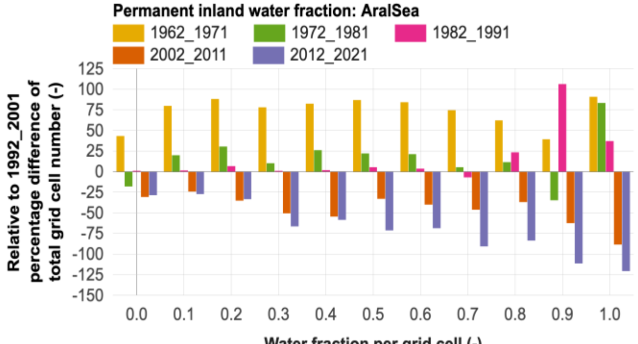


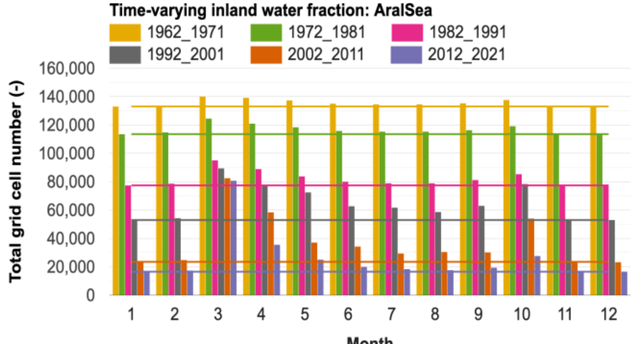








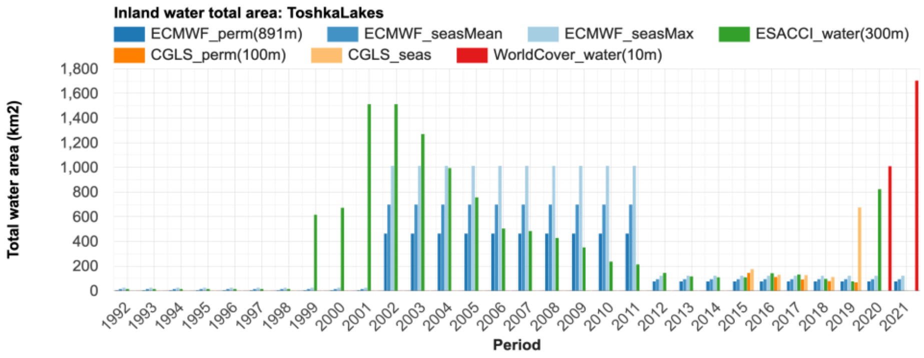


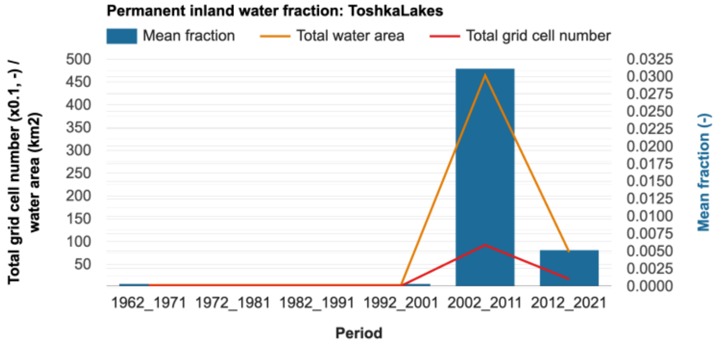


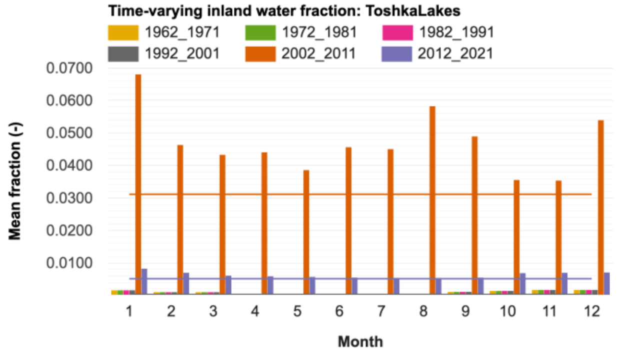
Funded by the European Union

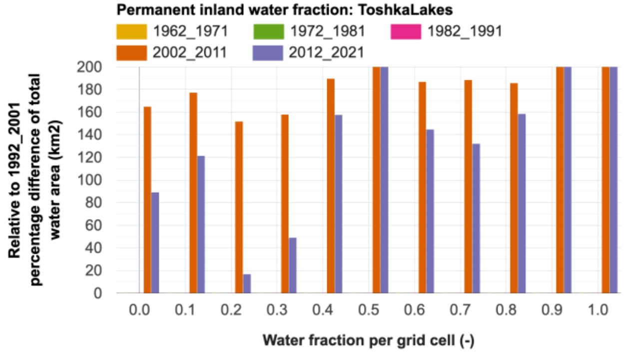
Comparison:
inland water at 1km
Toshka Lakes

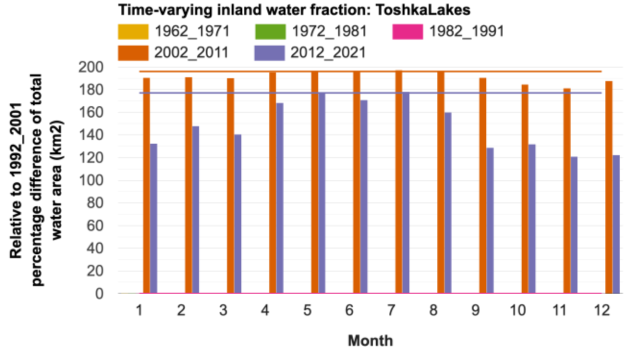
- Historical **formation and seasonality** of the Toshka Lakes are **well** captured (*second-row left and right-column plots*);
- Current maps lack up-to-date information (last available year 2021) and do **not well represent** the **current state**;
- Data comparison (*first-row plot*) shows **very good correlation** with **yearly information** of:
  - ESA CCI (**300 m** nominal resolution);
  - Copernicus CGLS (**100 m** nominal resolution);
- Data could **not pick up recent increase** in water distribution, that was picked up by:
  - ESA WorldCover (**10 m** nominal resolution).

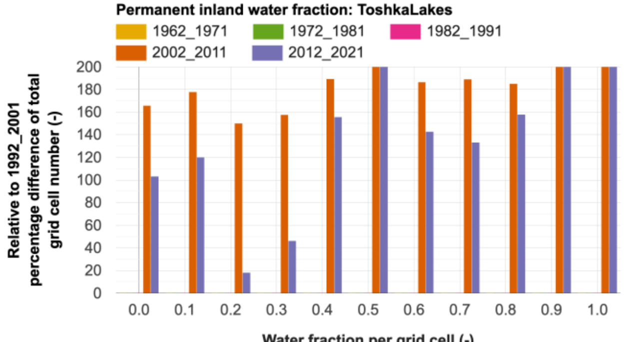


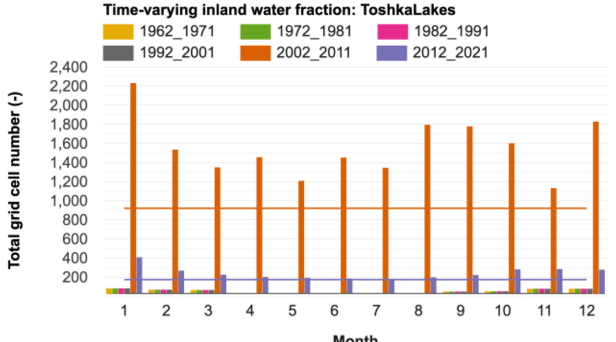












Summary

Funded by the European Union

- <u>Decadal monthly maps based on monthly 30 m resolution input data are generated:</u>
  - \+ **Input data used is open, up to date, consistent in time, and very high resolution** (15 to 100 m resolution);
  - − **Water input data use was challenging →** complex methodology to overcome:
    - ✔ **missing** data **over land** and over far away **ocean;**
    - ✔ data **limited** from **78 °N** to **60 °S;**
    - ✔ **missing islands;**
    - ✔ **unreliable** data far **north** (e.g. Greenland);
  - \+ **Methodology** developed is **automated**, reliable and **adaptable**;
  - \- Inland water is separated by mask – **constant ocean** borders, (e.g. **new islands** and/or **coastal** line **erosion** interchange with **inland water**), as Copernicus GLO30 is **static** and represents **year 2015**;
  - \+ In general, **good correlation** of the maps with high horizontal resolution yearly datasets, i.e. **ESA CCI** (300 m), **Copernicus CGLS** (100 m), **ESA WorldCover** (10 m).

<u>Future plans</u>

1. **test** generated **maps** in the offline/ forecast experiments;
2. **use maps as time-varying surface fields for ERA6Land**.

Funded by the European Union

Coordinated by ECMWF

CopERnIcus climate change Service Evolution - CERISE

Thank you!

The CERISE project (grant agreement No 101082139) is funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the Commission. Neither the European Union nor the granting authority can be held responsible for them.

Offline experiments

- **ijj7** - constant lakes (and lsm) from climate.v020, time-varying vegetation is off, control [experiment copied from David];
- **ijzg** - time-varying lakes (and lsm), static vegetation, mask is based on MAX land, correcting initial conditions in create_init_clim.ksh, correcting soil moisture level 1 and 2 in surface_model.ksh;
- **ijkg** - same as ijzg, but every time constant lakes (and lsm) are passed, no correction should be done anywhere [experiment is a methodology check].