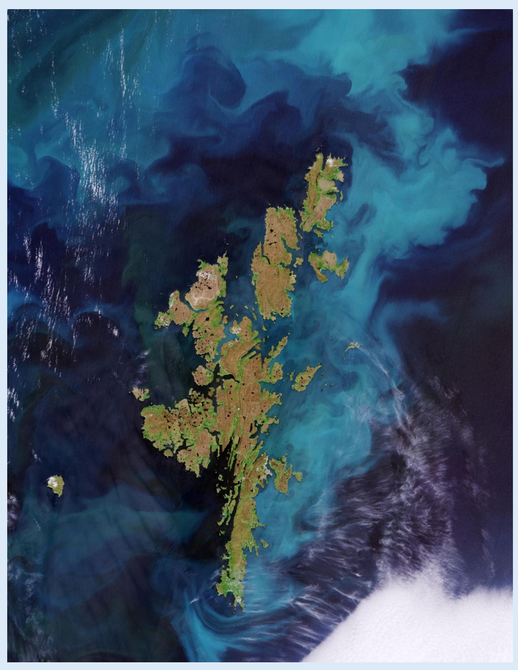
The next level: Quality metrics for climate indicators

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Level 1, 2 data



Algal blooms around the Shetland Islands
Contains modified Copernicus Sentinel data (2021), processed by ESA

Satellite and **in situ** radiance, reflectance, inherent optical properties (IOPs), biogeochemistry.

Metrological process established over the past decades (FRMs, QA4EO, *etc.*): **per-pixel quality flags** and **uncertainty estimates**. Correlation (time, space, spectrum) is less well-understood.

Completeness, **consistency**, **timeliness**, and other quality metrics subject to instrument (*e.g.* footprint) and observation (*e.g.* cloud) properties.

Level 3, 4 data

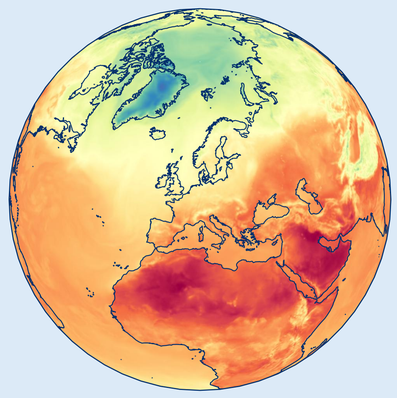
Level 3

Regridded and **gap-filled for consistency**.

Level 4

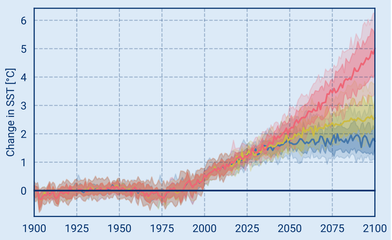
Model outputs based on lower-level data, *e.g.* net primary production.
(Re)analysis assimilates **diverse data** and forecast **models**, *e.g.* ERA5, ORAS5.
Seasonal forecasts and **climate projections** extend data into the near/far **future**, *e.g.* SEAS5, CMIP6.

Quality metrics are **less well-defined**. **Uncertainty** through **ensembles** (*e.g.* ERA5-EDA, CMIP6), but does this capture everything?



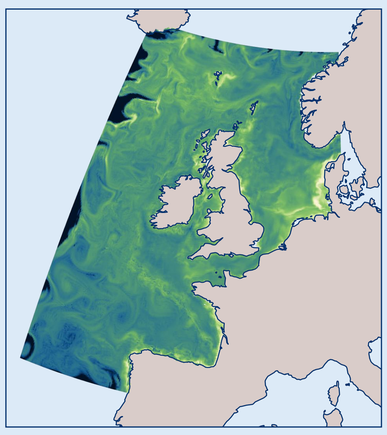
Hourly 2m air temperature from ERA5
doi:10.24381/cds.adbb2d47

Sea surface temperature rise in CMIP6
C3S Atlas (atlas.climate.copernicus.eu)



KNOWLEDGE GAP: Metrology for downstream products

Climate indicators: Level 5?

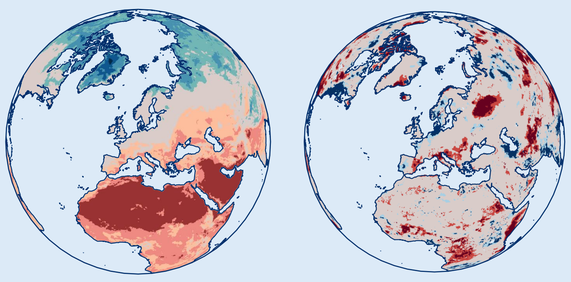


Euphotic-zone chl-*a* derived from climate projections (RCP-4.5, one-day snapshot)
doi:10.24381/cds.dcc9295c

Derived from observations, projections, forecasts, and reanalyses, indicators provide **practical information** for **downstream users** in specific **sectors**.

Example: **marine biogeochemistry derived from climate projections**, coupled physical and ecosystem models driven by climate projections. Use case is predicting climate change impact on the marine sector, *e.g.* biodiversity and fishery.

Other sectors: drought, thermal comfort, energy usage for heating/cooling, storm damage, *etc.*



Climate indicators derived from ERA5:
Left: Thermal comfort index (UTCI) from ERA5-HEAT
doi:10.24381/cds.553b7518
Right: Drought index (SPEI-1) from ERA5-Drought
doi:10.24381/9bea5e16

Reviewing 36 derived datasets in the **Copernicus Climate Change Service (C3S)**, we found a **knowledge gap** in the uptake of **quality metrics** and **propagation of uncertainty**.

Future indicators propagate underpinning **ensembles**. This provides a first-order uncertainty estimate, but does **not** probe inter- or intra-model **correlation** and **aggregation** effects.

Historical indicators do not provide uncertainty estimates except for ERA5-Drought's ensemble.

Propagating uncertainty to climate indicators can be complex: diverse **underpinning data** (often lacking uncertainty), complex **models**, and **processing steps** like aggregation, downscaling, gap-filling, regridding, *etc.*

Are these climate data fit for my purpose?

Users need to know that climate data are **trustworthy**, **traceable**, and **fit for purpose**. Decision-making based on climate data requires knowledge of data **provenance** and **key strengths** and **limitations**.

We are **exploring methods** to evaluate Level 3, 4, and 5 products in the same way as Level 1 and 2 data and to **propagate quality metrics downstream**. This will **allow users to assess** the accuracy, consistency, uncertainty, and thus fitness for purpose of climate indicators.

Ongoing **C3S EQC** (Evaluation and Quality Control; Dee+24) user consultations show that users want **actionable information** about **quality attributes** and **example applications** of a dataset.

What does data quality mean to you?

What do you think is missing?

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Figures generated using Copernicus Climate Change Service (C3S) data.
climate.copernicus.eu

Dee+24: *Are Our Climate Data Fit for Your Purpose?*
doi:10.1175/BAMS-D-23-0295.1

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