https://doi.org/10.5194/egusphere-2026-4209
Preprint. Discussion started: 27 August 2026

GC Insights: Choosing the right map projection, and what it means for scale bars and north arrows

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Abstract. Map projection choice is usually left to software defaults, yet it determines whether spatial patterns are shown faithfully or systematically distorted. Because every projection trades area, shape, distance, and direction differently, the validity of two common map elements, the scale bar and the north arrow, depends entirely on the projection chosen. A survey of 299 maps drawn at random from a frame of 27 geoscience journals finds that 1.7 % name their projection, 44 % give no way to determine it, and only 16 % draw a graticule, the one device that shows the geometry rather than approximating it. This Insight argues that projection should be a deliberate, purpose-driven choice, and that journals should require authors to declare the coordinate reference system in figure captions.

Scientists use maps to communicate spatial patterns in data: disease burden across countries, temperature anomalies by region, species distributions across continents. The choice of how to translate the curved surface of the Earth onto a flat page, the projection, determines whether those patterns are faithfully conveyed or systematically distorted.

Yet projection choice remains one of the most neglected decisions in scientific cartography. Defaults inherited from web mapping environments, or from software packages that prioritise rendering speed over analytical correctness, produce maps that misrepresent the phenomena they are meant to show. This is not a problem confined to student work or grey literature: Mercator world maps and unprojected geographic coordinates appear regularly in peer-reviewed journals, in disciplines such as epidemiology, ecology, geoscience, and climate science. The problem is not aesthetic. It is analytical. A wrong projection can inflate or compress regions, alter perceived spatial relationships, and bias the reader's interpretation of the data (Lapon et al., 2020; Kessler and Battersby, 2023). Two elements of map marginalia, the scale bar and the north arrow, make this problem concrete: their validity, and often their necessity, is determined entirely by the projection. Here I ask how often a published map actually lets a reader determine which projection was used, and what that means for the scale bar and north arrow whose validity depends on it. A survey of 299 maps drawn from the geoscience literature, reported below, answers both.

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Why projections matter

Every map projection is a mathematical transformation of the sphere onto a plane. No transformation can simultaneously preserve area, shape, distance, and direction; each projection trades distortion in one property for accuracy in another. The fundamental principle of cartographic practice is that the choice of projection must be driven by the purpose of the map (Snyder, 1987).

The Mercator projection, designed in 1569 for nautical navigation, preserves local angles and shapes, a property essential for plotting compass bearings. For that purpose, it remains valid (Monmonier, 2004). For thematic maps, where the visual extent of a region should correspond to its actual surface area, it is actively misleading: at 60° latitude, areas appear roughly four times larger than they are, and Greenland looks comparable to Africa, which is some 14 times larger. Mercator persists in peer-reviewed publications as a default inherited from web tile rendering, where its conformal properties serve technical rather than communicative purposes (Battersby et al., 2014).

Almost as widespread, and as problematic, is the use of geographic coordinates, longitude and latitude, treated as Cartesian X and Y, as a de facto projection. This equirectangular representation is not conformal, not equal-area, and not equidistant in any meaningful sense. It is the result of not choosing a projection at all, and in most GIS environments, it is what happens when the analyst accepts the default.

For global thematic maps, equal-area projections are the appropriate default. Equal Earth, Mollweide, and Goode's Homolosine all preserve relative surface areas, so that the visual weight of a region reflects its actual extent. For continental maps, the choice depends on geographic shape and purpose: Lambert Azimuthal Equal Area (EPSG:3035) is the standard for European statistical cartography; Albers Equal Area Conic (EPSG:5070) is the conventional choice for North America. Conformal projections, Lambert Conformal Conic and Universal Transverse Mercator, suit topographic and navigational work, where shape matters more than area. The principle is constant: match the projection to the distortion the map can tolerate given its purpose (Fig. 1; Šavrič et al., 2019; Field, 2018).

A useful diagnostic tool is the Tissot indicatrix, a set of circles of identical size placed at regular intervals across the globe. When projected, equal-area projections keep all circles at the same area, though their shapes may differ; conformal projections keep all circles round, though their sizes may differ; compromise projections show moderate deviations in both. Visualising the indicatrix on a candidate projection reveals the geography of its distortion before one commits to it (Fig. S1).

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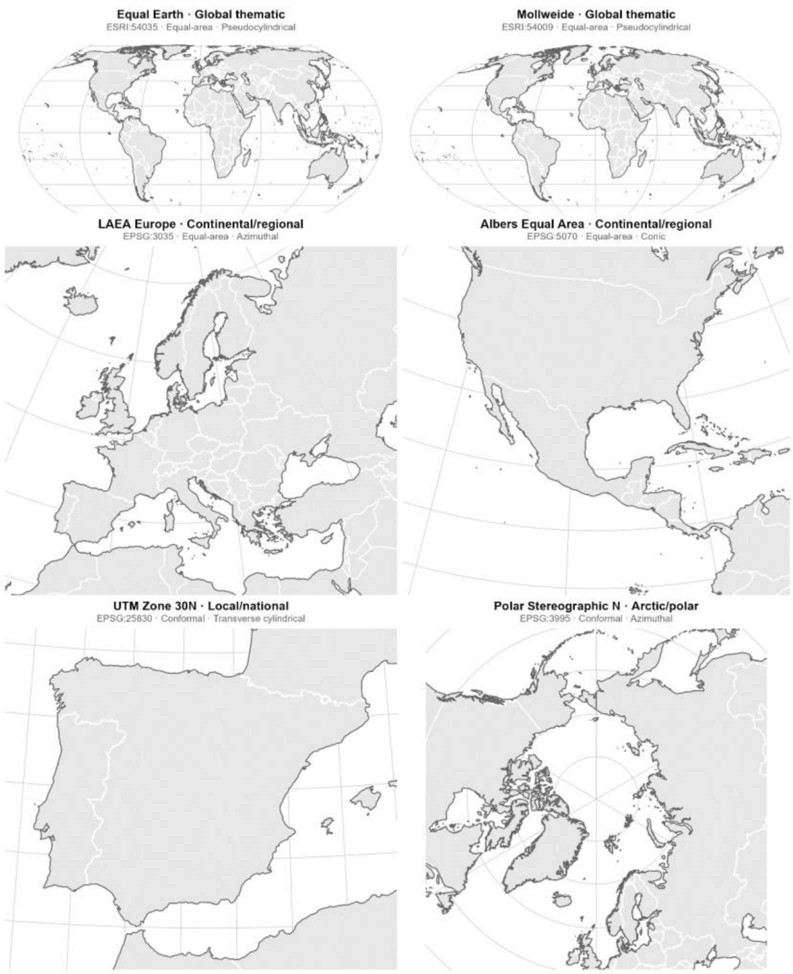

Figure 1: Principal map projections by use context. Each panel shows a representative projection for a different spatial scale or geographic context: global thematic mapping (Equal Earth, Mollweide), continental and regional mapping (Lambert Azimuthal Equal Area for Europe, Albers Equal Area Conic for North America), large-scale local mapping (Universal Transverse Mercator, zone 30N), and polar mapping (Arctic Polar Stereographic). Graticule lines are shown in geographic coordinates (WGS84). Projection family and area-preservation properties are indicated in each panel.

What the published record shows

To see how far this matters in practice, I drew a random sample of 299 maps, one per article, from 299 articles sampled from a frame of 27 Copernicus geoscience journals published between 2016 and 2025, stratified by domain. For each map, I recorded only what a reader can see on the page: whether a coordinate system is identifiable, whether a scale bar, north indicator, or graticule is drawn, and the mapped extent. Methods, protocol, and full tables are given in the Supplement.

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Seven of the 299 maps, 1.7 % (95 % CI 0.6-4.3), name their projection. In 44 % (38-50) the projection cannot be determined at all, because no coordinate system is visible on the map, or because degree labels appear with no geometry from which a projection can be inferred. A reader is therefore usually in no position to judge how the map has treated distance and direction. Scale bars turn out to be a large-scale convention: 68 % of local maps carry one, against 3 % of global maps. Global maps are, in turn, where the projection is least often chosen with any care: of those that draw coordinate lines at all, 76 % (54-89) show a rectangular, evenly spaced degree grid, longitude and latitude plotted as x and y, which stretches area toward the poles by 1/cos(latitude): twice over at 60°, nearly four times at 75°. A map centred on a pole cannot make that mistake, since plate carrée stretches the pole itself into a line; such maps are necessarily projected, yet even there only 2 of the 39 sampled state which projection was used.

What the scale bar reveals

A scale bar encodes the local relationship between map distances and real-world distances. In any projection that is not perfectly equidistant, that relationship is not constant: the bar is accurate where it is placed and increasingly approximate elsewhere. In the Mercator projection, the linear scale at 60° latitude is twice that at the equator, so a bar placed at the bottom of a world map is correct near the equator and wrong by 100 % in Scandinavia. A scale bar on a global projection is a local truth presented as a global fact; the quieter failure in the survey is at local scale. A map drawn in unprojected geographic coordinates already stretches east-west distances by 41% at 45° latitude and threefold at 70°, and 55% of the local maps sampled provide no way to tell whether that is happening. The failure is not the absurd bar on a world map; it is the plausible bar on a small map whose projection is never stated. This is a projection problem, not a design problem. In UTM, accurate within a 6° longitude strip to better than 0.1 %, a centred bar is essentially correct across the full map. Where scale varies substantially, the bar should indicate the latitude at which it is valid, or give way to a labelled graticule from which the reader can derive distance directly.

What the north arrow reveals

A north arrow indicates the direction of north (Monmonier, 1996). In cylindrical projections, meridians are straight vertical lines and true north is vertical everywhere: the arrow states what the reader already knows. In pseudocylindrical and conic projections meridians converge, so north is vertical only along the central meridian; in azimuthal projections the variation can be extreme. This rarely bites in the surveyed literature: three-quarters of the world maps that draw any coordinate lines draw them as a straight, rectangular grid, meridians vertical by construction. Where meridians are straight, the arrow is redundant; where they are not, the graticule is the honest device, since it shows the geometry directly rather than approximating it at one point. Only 16 % of the sampled maps draw one.

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Making deliberate choices

The analogy with colour scale selection is direct. The persistence of rainbow palettes in scientific figures (Borland and Taylor, 2007) reflects the same dynamic as the persistence of Mercator in scientific maps: a default adopted for technical or historical reasons, never revisited, and now applied regardless of whether it serves the data (Crameri et al., 2020; Stoelzle and Stein, 2021). Just as perceptually uniform colour maps should be chosen because they encode data honestly, projections should be chosen because they preserve the property- area, shape, or distance- that matters for the scientific question. The marginalia follow from that choice: neither the bar nor the arrow should be included or omitted, by default. Most author guidelines specify axis labels, colour accessibility and statistical reporting, but say nothing about map projections. Journals that have already adopted policies on perceptually uniform colour scales could extend that logic and require one line in every map caption giving the coordinate reference system. The tools exist to make the choice easy (e.g. Projection Wizard; Šavrič et al., 2016); the editorial expectation that they be used is still missing.

Code and data availability

The coded dataset, the analysis code, and the coding protocol fixed before coding began are archived at [Zenodo https://doi.org/10.5281/zenodo.21978579]. The survey draws only on open-access articles published by Copernicus Publications, all under CC BY, which is what allows the coding to be released in full (Supplement, Sect. S6).

Author contributions

D. Royé conceived the idea, wrote the manuscript, and prepared the figures.

Competing interests

The author declares that they have no conflict of interest.

Financial support

D.R. is supported by a ‘Ramón y Cajal’ fellowship programme of the Spanish Ministry of Science and Innovation (RYC2023-042824-I).

Ethical statement

This study did not involve human participants, personal data, or animal subjects. It is based on publicly available geospatial data, and therefore no ethical approval or informed consent was required.

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