INTRODUCING NATURAL EARTH DATA - NATURALEARTHDATA.COM

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ABSTRACT:
Natural Earth is a public domain, map dataset available at 1:10, 1:50, and 1:110-million scales. Announced at the 2009 NACIS (North American Cartographic Information Society) annual meeting in Sacramento, California, the goal is to give cartographers an off-the shelf solution for creating small-scale world, regional, and country maps. It has several features of interest to mountain cartographers producing small-scale physical maps: rendered shaded relief images and GIS labels for many mountain peaks, ranges, and other physical features. But perhaps more importantly, it includes other reference themes that fit that physical geography.

Natural Earth data builds on Tom Patterson's Physical Map of the World presented at the 2008 ICA Mountain Cartography Workshop, Lenk, Switzerland. With NACIS backing, we have launched a new website, naturalearthdata.com, where you can download Natural Earth and updated versions of Natural Earth Raster imagery of Natural Earth I and II raster imagery in perfect registration with vector linework. Both political and physical features are included in Natural Earth data.

Natural Earth solves a problem that many cartographers face: finding vector data for making publication-quality small-scale maps. In a time when the web is awash in interactive maps and free, downloadable vector data, such as Digital Chart of the World and VMAP, mapmakers are forced to spend time sifting through a confusing tangle of poorly attributed data. Many mapmakers working under tight project deadlines must use manually digitalized bases instead.

Small-scale map datasets of the world do exist, but they have their problems. For example, most are crudely generalized—Chile's fjords are a noisy mess, the Svalbard archipelago is a coalesced blob, and Hawaii has disappeared into the Pacific two million years ahead of schedule. They contain few data layers, usually only a coast and country polygons, which may not be in register. The lack of good small-scale map data is not surprising. Large mapping organizations that release public domain data, such as the US Geological Survey, are not mandated to create small-scale map data for a small user community that includes mapmaking shops, publishers, web mappers, academics, and students—in other words, typical mountain cartographers. Natural Earth fills this oft-overlooked but important niche.

Keywords: *Natural Earth, website, downloadable vetor data, interactive maps.*

1. COLLABORATION

Natural Earth data is a collaboration involving many volunteers. Nathaniel Vaughn Kelso and Tom Patterson began working on the project in late 2008. Following the path of least resistance, the idea was to repurpose existing data that we already had as an integrated world dataset at three map scales. The 1:50 million and 1:110 million-scale data comes from bases developed by Dick Furno and additional staff at the Washington Post for quick turnaround newspaper mapping. The Washington Post Legal Department kindly granted us permission to use these data. The kernel for the 1:10 million data was a compilation by

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Patterson for the "Physical Map of the World," consisting of coastlines, rivers, lakes, and physical feature labels. Expanding and improving on this foundation has been our chief activity. The core team has now grown to include Tanya Buckingham, who coordinates data attributing by Ben Coakley, Kevin McGrath and Sarah Bennett at the University of Wisconsin Cartography Lab; Dick Furno as populated places specialist; Nick Springer as the website developer; and Lou Cross as NACIS liaison. A cast of consultants, many regulars on the Cartotalk.com discussion forum, assisted with place names for various world regions. They include Leo Dillon, Hans van der Maarel, Will Pringle, Craig Molyneaux, Melissa Katz-Moye, Laura McCormick, Scott Zillmer and fellow staff at XNR Mapping. Work continues apace on Natural Earth as we write this article.

2. DATA FOR CARTOGRAPHY

We developed a world base map data suitable for making a variety of visually pleasing, well-crafted maps. Unlike other map data intended for scientific analysis or military mapping, Natural Earth data is designed to meet the needs of mainstream production cartographers. Maximum flexibility was a goal. For example, Natural Earth data comes in ESRI shapefile format, the Geographic projection, and WGS datum, which are de facto standards for vector geodata.

Neatness counts with Natural Earth. The carefully generalized linework maintains consistent, recognizable geographic shapes at 1:10m, 1:50m, and 1:110m scales. As Natural Earth data was built from the ground up, you will find that all data layers align precisely with one another. For example, where rivers and country borders are one and the same, the lines are coincident.

Natural Earth data, however, is more than just a collection of pretty lines. What lies beneath the surface, the data attributes, is equally important for mapmaking. Most data contain embedded feature names, which are ranked by relative importance. Up to eight rankings per data theme allow easy custom map "mashups" to emphasize your map's subject while de-emphasizing reference features.

Other attributes facilitate faster map production. For example, width attributes assigned to rivers allow you to create tapered drainages with ease. Assigning different colors to contiguous country polygons is another task made easier thanks to data attribution.

Other key features include:

- Major world peaks with name and elevation attributes obtained from Peakbagger.com.
- Vector physical features include major world mountain ranges with name attributes and bounding box extent so you know the Himalayas are larger than the Carpathians.
- Large polygons, such as bathymetric layers, are split for more efficient data handling.
- Projection friendly—vectors precisely match at 180 degrees longitude. Lines contain enough data points for smooth bending in conic projections, but not so many that processing speed suffers.
- Raster data include grayscale-shaded relief and cross-blended hypsometric tints derived from the latest NASA SRTM Plus elevation data and tailored to register with Natural Earth data.
- Optimized for use in web mapping applications, such as tiles for Google Maps mashups, with built-in scale attributes to direct features to be shown at different zoom levels.

1:10 million data layers:

Geographic lines – Polar circles, Tropical circles, International dateline, and Equator

Graticules – 1-, 5-, 10-, 15-, 20-, and 30-degree increments

Glaciated areas – Polygons derived from DCW, except for Antarctica derived from

MOA. Includes name attributes for major polar glaciers.

Antarctic ice shelves – Derived from 2003-2004 MOA. Reflects recent ice shelf collapses (circa mid-2009).

Bathymetry – Nested polygons at 0, -200, -1,000, -2,000, -3,000, -4,000, -5,000, -6,000, -7,000, -8,000, -9,000, and -10,000 meters. Created from SRTM Plus.

Rivers – Ranked by relative importance. Includes name and line width attributes.

Lakes – Ranked by relative importance, coordinating with river ranking. Includes name attributes.

Lake Centerlines – Segments for creating continuous rivers without reservoir and lake interruptions. Don't want minor lakes? Turn on their centerlines to avoid unseemly data gaps.

Coastline – Ocean coastline, including major islands. Coastline is matched to land and water polygons.

Islands – Additional ocean islands ranked to three levels of relative importance.

Reefs – Major coral reefs from WDB2.

Urban polygons – derived from 2002-2003 MODIS satellite data.

Populated places – point symbols with name attributes. Includes major cities and towns, plus significant smaller towns in sparsely populated regions.

Countries – matched boundary lines and polygons with names attributes. Includes disputed boundaries and areas, breakaway regions, sub-national territories, dependencies.

Pacific nation groupings – boxes for keeping these far-flung islands tidy.

Water boundaries – Includes limited indicator lines for 200-mile nautical limits, plus disputed, treaty, and median lines.

First order admin (provinces, departments, states, etc.) – internal boundaries and polygons for all but a few tiny island nations. Includes names attributes.

Physical features – polygon and point labels of major physical features and marine bodies of water.

3. DATA DEVELOPMENT

Since Natural Earth data is for visual mapmaking, we prepared the base layers in Adobe Illustrator in conjunction with Avenza MAPublisher import and export filters. Illustrator offered us flexible tools for editing lines and polygons, organizing data on layers, and inspecting the final data in a map-like form. A variety of third-party plug-in filters and scripts, some written by Kelso, were essential for linework generalization and other tasks.

World Data Bank 2 was the primary vector data source that required significant modifications. For example, we found that the entire West Coast of the United States was about seven miles west of its true position and adjusted it accordingly. Slight adjustments to river positions better matched them to shaded relief derived from recent satellite data. For Antarctica, we completely abandoned World Data Bank 2. Here, the coast, glaciers, and ice shelves derive from 2003-2004 NASA Mosaic of Antarctica, a MODIS product. We also updated the data to reflect recent ice shelf collapses.

Contributors from around the globe researched additional feature names beyond those original to Patterson's Physical Map of the World. Attributing the data was performed in ArcGIS by the team at the University of Wisconsin, and in Adobe Illustrator using MaPublisher by volunteers around the world working with Kelso.

4. FUTURE ACTIVITY

We regard the initial release of Natural Earth data as a starter dataset that will be periodically updated. With any project as complex as this, flaws and omissions are bound to emerge, requiring our attention. One proposal is to form a Natural Earth map data committee to incorporate information and coordinate updates from users, perhaps using a wiki model. Rivers, lakes, and first-order admin are components still in need of refinement. Possible data for future updates include transportation (roads and railroads), time zones, and terrestrial hypsography. If you have ideas for Natural Earth, please drop us a line at update@naturalearthdata.com.

5. RASTER DATA

Natural Earth raster data largely derives from previous Natural Earth products created by Tom Patterson over the last several years, available at shadedrelief.com, plus we offer new data themes (Figure 1). The raster files are available at 1:10 million and 1:50 million-scales and at multiple resolutions up to 21,600-pixels wide. The downloadable files are in GeoTIF format, Geographic projection, and WGS84 datum.

Natural Earth raster data tightly integrates with the vector data described previously. For example, the 1:10 million vector coastlines and drainages, and mountain peaks register precisely with raster relief art that mapmakers will place below the vectors. Some of the raster data themes include optional "baked in" content, such as land cover, shaded relief, ocean water, drainages with lakes, glaciers, and Antarctic ice shelves. With these options mapmakers have the choice of using an elaborate raster base map or a simpler one more suitable for combination with vector elements.

Natural Earth raster data themes include:

Natural Earth 1 – Satellite-derived land cover data and shaded relief presented with a light, natural palette suitable for making thematic and reference maps. Terrestrial land cover derives primarily from Vegetation Continuous Fields (VCF) data obtained from the

University of Maryland, Global Land Cover Facility. VCF derives in turn from NASA MODIS satellite data (*Patterson and Kelso 2004*).

Natural Earth 2 – This data derived from Natural Earth 1 portrays the world environment in an idealized manner with little human influence. The data depicts the potential vegetation of regions rather than existing land cover. The softly blended colors of Natural Earth 2 are ideal for historical mapping, because it depicts the world environment much as it was before the modern era.

Bathymetry – Rasterized ocean depth polygons in a layered Photoshop file that you can manipulate for color and then save a GeoTIF to use with the provided TFW world file. Each Photoshop layer contains separate depth layers in 1,000-meter increments, plus the 200-meter depth layer representing the edge of the continental shelf. The file includes an ocean mask and land shaded relief reference layers.

Shaded Relief – Basic grayscale shaded relief of land areas only derived from downsampled SRTM30 Plus elevation data clipped to Natural Earth vector coastlines. A flat gray tint occupies water areas.

Ocean Bottom – Blended depth colors and relief shading of the ocean bottom derived from CleanTOPO2 data. Derived from SRTM30 Plus, manual editing to these data removed unsightly artifacts, such as the tracks of survey vessels collecting sounding data. The ocean color extends beneath land areas as a flat tint and requires shoreline masking with 10 million-scale Natural Earth vector data, or shoreline data of your own.

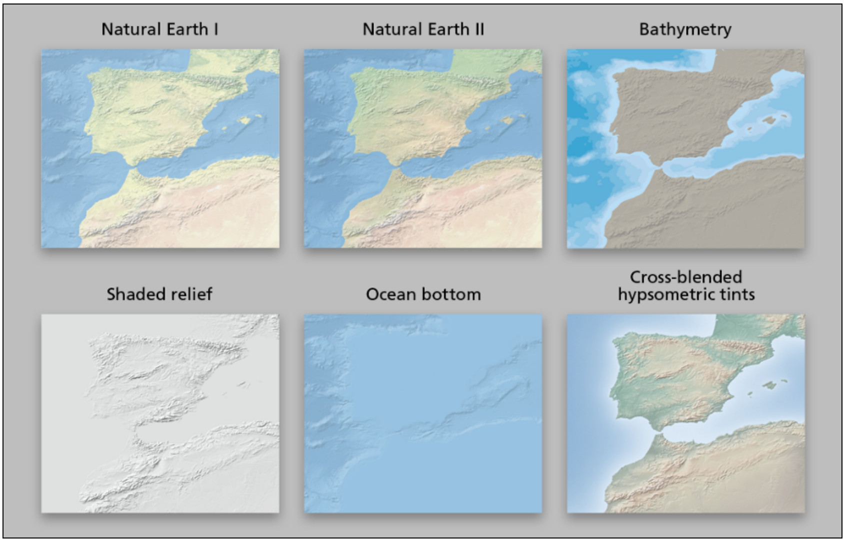

Fig. 1 Natural Earth offers six varieties of raster data

6. CROSS-BLENDED HYPSOMETRIC TINTS

In addition to the data described above, the Natural Earth data website introduces an entirely new type of raster map. Cross-blended hypsometric tints offer a partial solution to a long-standing map reading problem: many people misidentify hypsometric tints not as elevation colors but as vegetation or climate regions. Studies show that this is the case with young map readers (*Patton and Crawford 1978, Sandford 1980*). Conventional hypsometric tints typically show green in the lowlands, yellow in mid elevations, and red in the highlands. According to anecdotal evidence, these colors incorrectly suggest to untutored map-readers that forests cover the parched lowlands of the Persian Gulf and a hot desert climate prevails on the high-elevation Greenland ice cap.

Cross-blended hypsometric tints instead use modified elevation colors for lowland regions that people will more likely associate with the natural environment. The Sahara is dusty brown, northern Russia is boreal forest green, the Mekong delta is jungle green, and Antarctica is icy blue-grey. As in nature, the map colors gradually blend into one another across regions (x and y axis) and from lowlands to highlands (z axis), hence the name cross-blended hypsometric tints (**Fig. 2**).

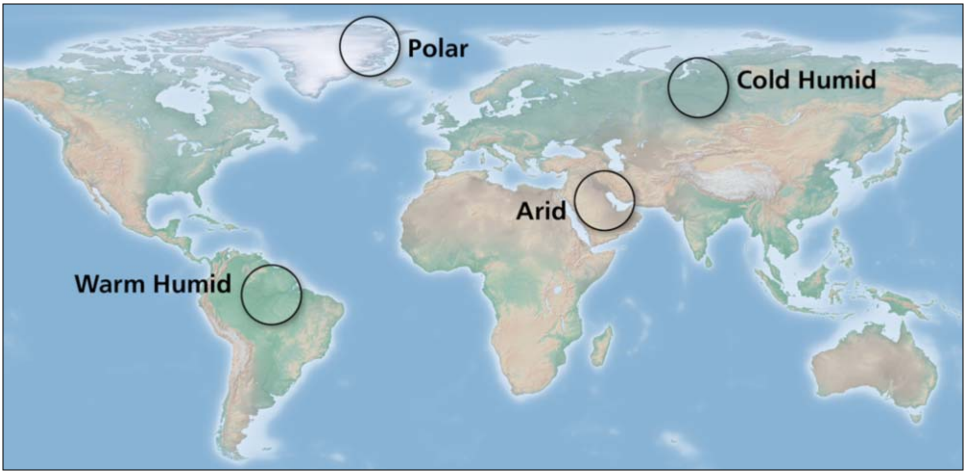

Fig. 2 Cross-blended hypsometric tints use lowland colors that people associate with regional environments

6.1. Creating cross-blended hypsometric tints

To create cross-blended hypsometric tints, we used Natural Scene Designer Pro and Adobe Photoshop software. The procedure involved creating four separate hypsometric tint maps with lowland colors customized to represent different environmental regions—warm humid, cold humid, arid, and polar. Careful merging these maps in Photoshop produced the final map.

Determining the fuzzy, generalized boundaries between environmental areas involved references to climate maps in atlases. For example, polar regions are commonly defined as having an average temperature below 10 degrees Celsius for the warmest month of the year, typically July in the northern hemisphere and January in the southern hemisphere. Importing this isotherm as a Photoshop layer mask and blurring it provided a convenient way to map polar environments. Similar methods based on the Köppen climate classification system allowed us to identify the other regions. In the Köppen system, the Af and Am classification designate warm humid (tropical) regions and Db, Dc, and Dd designate cold humid (continental) regions.

Before mapping these climate regions, however, we first needed to create a rather conventional hypsometric color ramp in Natural Scene Designer Pro 5.0: lowland greens blending upwards into yellows then reds and finally whites at the highest elevations. These colors are typical of those now used in atlases and popular wall maps, although we selected more muted palette to better correlate with natural colors found in the environment. Determining the elevation breaks for the colors involved trial and error in Natural Scene Designer Pro and largely followed a geometric progression. Because the majority of Earth's landmass is below 1,000 meters in elevation, these areas require more color differentiation than higher elevations that occupy a relatively small amount of the total land area (*Imhof, 1982*). The final selection of elevation zones and the colors in them was largely based on our personal taste.

Having created satisfactory conventional hypsometric tints, the next step involved swapping out the lowland green for a color that better represents desert lowlands. Selecting this color required considerable experimentation. Browns with a value to similar to the lowland greens invariably looked dark, somber, and uninteresting over the vast areas that they covered. Below sea level areas such as the Caspian Basin South Australia were especially problematic. Identifying a brown that would complement the blue-green lowland tint was another consideration. We ended up selecting a light brown hue with a hint of olive green.

Next, we created hypsometric tints for polar areas. These are different from all other regions in that they dispense with the yellows, reds, and whites at the upper elevations in favor of a nearly monochromatic scale ranging from blue-grey lowlands to blue-white highlands. Having Antarctica and Greenland appear with icy colors would better match the colors associated with the actual environment of these places, so we thought. The polar elevation scale does not extend as high as the scales of other regions, only to 4,500 meters, because of the comparatively lower maximum elevations found there (**Fig. 3**).

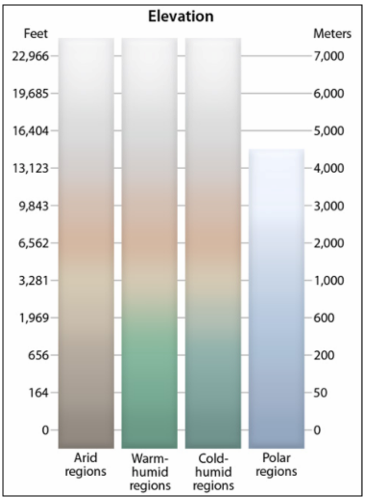

Fig. 3 Lowland colors in the first three elevation scales (from left) depict generalized environments. Above 1,000 meters the colors are identical and rather conventional. The polar scale uses unrelated colors and is shorter because no peaks exceed 5,000 meters in these regions

With these environmentally adjusted hypsometric tints created, we had the foundational elements needed for compositing the final map in Photoshop. In addition to masking the tints based on climate regions, we merged shaded relief on top of it all. The water layer included with some versions of the cross-blend hypsometric tints available on the website depict shallow waters as very light blue. Because the terrestrial lowlands are comparatively dark at sea level, the light shallow waters provided adequate contrast with the land, enhancing the figure-ground effect.

Cross-blended hypsometric tints—do they work?

We suspect that cross-blended hypsometric tints are less effective for conveying relative elevation than conventional hypsometric tints. Multiple color scales that merge into one another probably impede the reading of comparative elevations worldwide. However, mapmakers have downloaded cross-blended hypsometric tints over 9,000 times in the year since the initial release. Perhaps the popularity of these data is not because elevation is critically important information to average map users, but for the pleasing colors that they bring to a map. This explanation possibly applies to the majority of small-scale maps that display elevation colors. If this is the case, the advantage of cross-blended hypsometric tints is the holistic portrayal of our world that they provide: casual map-readers now will see places like Kuwait as a lowland desert, rather than rainforest. Or so we would hope. User testing of cross-blended hypsometric tints is needed to evaluate this assumption.

7. CONCLUSION

With the release of Natural Earth, mountain cartographers making small-scale physical maps now have integrated, fully attributed, ready-to-use vector and raster datasets at their disposal. Vector labels indicating peaks and mountainous regions, and raster base maps with relief and hypsography, are available for such purposes. Creating this dataset was joint effort involving many people, including the mountain cartography community, all of whom deserve our gratitude.

Since released in December 2009, the NaturalEarthData.com site has enjoyed over 75,000 visits from nearly every country in the world with the majority (more than 62%) coming from the United States, Germany, Spain, United Kingdom, Canada, and France. The remainder is split between other countries in Europe and the rest of the world. Individual files from Natural Earth have so far been downloaded more than 90,000 times. The more detailed 1:10 million scale themes are most popular with equal interest in the raster, cultural vectors, and physical vectors.

The Natural Earth project can use your help to stay current with our changing world and to expand our data coverage. In particular, we're looking for more detailed rivers outside of North America and Europe, and major parks and roads worldwide. To volunteer, please contact the authors at update@naturalearthdata.com.

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