Cartographic Perspectives

Journal of the
North American Cartographic Information Society
Number 56, Winter 2007

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From the Editor

Dear NACIS members,

You are holding CP 56 in your hands, reflecting the efforts of past editor Scott Freundschuh (who marshaled the pair of featured articles through the peer-review process) and myself, your new editor. I thank members of the editorial board and the section editors for their efforts in shaping the content of CP. Jim Anderson, our assistant editor, has pulled together a morass of text, graphics files, and other bits into a coherent and engaging issue.

Academic journals reflect the personalities and interests of their editors, but it is certainly not only about the editor. Indeed, it is vital that CP reflects the diversity of the NACIS membership, one of my goals as editor of the journal. An open panel session at the last NACIS meeting and informal discussions with NACIS members generated a significant list of ideas, from small tweaks in journal design to ideas for major new sections for the journal. Some of those ideas are here for your perusal in CP 56, and more are to come, including a revival of the Fugitive Literature column, interviews, exploratory essays, and peer-reviewed maps and software. The color cover of the journal will be used in different ways, and I am investigating the inclusion of a poster-sized map insert, publishing interesting maps with intellectual and cartographic merit that may not otherwise be printed.

Promoting the journal as a place to publish a diversity of materials

(*continued on page 3*)

In this Issue

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(*letter from editor continued*)

related to cartography is important, as more submissions mean a better journal. To this end I have created a CP promotional sheet (see the PDF at the CP page at nacis.org) and CP business cards. You can print the promotional sheet and distribute it at meetings or email it to interested colleagues. The business cards can be used in the same way and have been distributed to CP Editorial Board members. Any way that you can help get people to contribute material for any and all sections of CP is appreciated, and, indeed, vital to the success of the journal. If you are talking to someone and they are engaged in some interesting cartographic work, encourage them to document it in CP.

Another of my goals is to increase the visibility of *Cartographic Perspectives.* CP should soon be included, full text, in Ebsco's Academic Search Complete (available by mid 2007). This database of academic journals is typically available to universities and some public libraries. Full text availability is vital, as scholars want their work to be accessible to other scholars. In the past, CP has been available to members and on the shelves of some academic libraries, limiting access to the broader scholarly and cartographic community. Full-text availability will open CP to a much broader readership, and should increase submissions and the visibility of the journal. Other indexing and accessibility issues are currently being investigated.

The content of this issue is diverse. The subject of the cover as well as the Visual Fields images and essay by Denis Wood is personally important to me, as it documents the work of two artists who were my first contact with the emerging interest in maps and mapping among artists. This interest, I would argue, is not merely esoteric, but cuts to the core of important intellectual issues in cartography. Wood also provides a response to Mark Denil's comments (in CP 55) on Wood's opening article in the special Art & Mapping issue (CP 53). "A Map Is an Image Proclaiming its Objective Neutrality" is more about the nature of maps than about map art in particular. I don't think the debate stops here! The two featured articles in this issue, on uncertainty in isometric mapping and visualization issues with climate data reflect the continuing state of the art in empirical research in cartography, driven by changes in technology but situated within several decades of evolving cartographic theory, coping with uncertainty and a complex, ever changing world we are attempting to understand. Reviews of books on remote sensing, literature and mapping, and map theory follow. "Achieving Historical Map Effects with Modern GIS," in the renamed *Mapping: Methods & Tips* section of the journal, clearly reflects the sprit of making maps that pervades *Cartographic Perspectives,* addressing in a methodical manner the production of new maps with new technologies reflecting evocative characteristics of maps of the past.

Cartography is all of the things in this issue. NACIS reflects this diversity, and that is one of the reasons it is such a great organization. If you don't see yourself or your interests in CP, *do* something, *make* something, *write* something, *map* something and send it along.

John Krygier
Editor

A Map Is an Image Proclaiming Its Objective Neutrality: A Response to Denil

Denis Wood
Independent Scholar
Raleigh, NC

I'd like to thank Mark Denil for his thoughtful response to my article "Map Art."[1] The article, and the catalogue of 218 map artists that accompanied it, indeed all of the articles in what was essentially a special issue of *Cartographic Perspectives* devoted to map art, were necessarily preliminary forays into what is still largely a *terra incognita*.[2] All were offered in the full expectation of being, at the very least, amended. Omissions, for example, were egregious. Not only did I fail to include in the catalogue Andy Warhol, whose map of missiles in the USSR is fast becoming an iconic exemplar of map art,[3] but through sheer inadvertence our own Steve Holloway, whose map art has long since graced the cover of *Cartographic Perspectives*.[4] Such lapses should be made good once the catalogue goes online as a wiki, but the wiki will not address the conceptual problems Denil highlighted. The following remarks, therefore, are intended to clarify what I have been claiming makes a map a map, that is, what I've been calling the map's mask.

The map's mask establishes its alienation

Denil agrees with me that all maps wear this mask. "This, at least," Denil says, "is uncontroversial: the mask refers to the signs employed by a map to connote trustworthiness." That, however, is pretty much the extent of our agreement, because for me – to put the matter as inflammatorily as I can – by proclaiming its own trustworthiness the map establishes its alienation. Any discourse proclaiming its own trustworthiness is alienated discourse, what Roland Barthes called myth.[5] That the map was a kind of myth, in Barthes' sense, was what John Fels and I had demonstrated in our 1986 *Cartographica* paper, "Designs on Signs: Myth and Meaning in Maps," where we isolated the codes chiefly responsible.[6] Six years later I called the product of these codes "the mask *no* map goes without" in the lecture "How Maps Work" with which I inaugurated The Power of Maps exhibition I'd co-curated for the Cooper-Hewitt National Museum of Design.[7] Shortly thereafter, in "What Makes a Map a Map," a lecture I read at the Yale-Smithsonian Material Culture Seminar on Maps, I distinguished a class of map-related objects that *had not put on the mask*, were not alienated, and therefore not maps.[8] This class included experimental and other sketch maps.

". . . an essential property of maps: their objectness*, their* objectiveness*, their* "objectivity.""

In doing so I characterized an essential property of maps: their *objectness*, their *objectiveness*, their "*objectivity*."[9] This "objectivity" was established in the world of *inter*personal discourse – in talk, in conversation – whenever a communication was "sealed" as being "in the world" by various forms of *interpersonal validation*, especially by signs of assent: nods, repetitions, significant glances. In this *inter*personal world such discourse was not necessarily alienated. But in the *trans*personal world where maps as more or less permanent, transmissible descriptions of territorial relations find their peculiar utility, such discourse was *necessarily* alienated because the quality of being in the world (of being objective) was asserted not only without assent being granted (or even negotiated), but as though assent *had been granted*, that is, as though there were nothing problematic about the communication.

For me this problem of "objectivity" had first become acute in 1970-71 when I was struggling to make sense of the three hundred-some experimental sketch maps I'd collected for my dissertation from American teenagers on their first visits to London, Rome, and Paris.[10] The goal was to learn something about how environmental knowledge changed over time, so in each city I'd collected sketch maps early in the kids' visit, toward its middle, and near its end. The question, of course, was how to measure the changes. Kevin Lynch, who'd pioneered the analysis of experimental sketch maps, rejected the idea of comparing such "subjective" images to "objective" data:

> To compare with these subjective pictures of the city, such data as air photos, maps, and diagrams of density, use, or building shape might seem to be the proper "objective" description of the physical form of the city. Considerations of their objectivity aside, such things are entirely inadequate for the purpose, being both too superficial and yet not generalized enough. The variety of factors which might be evaluated is infinite, and it was found that the best comparisons to the interviews was the record of another subjective response, but in this case a systematic and observant one … While it was clear that the interviewees were responding to a common physical reality, the best way to define that reality was not through any quantitative, "factual" method but through the perception and evaluation of a few field observers.[11]

". . . I was to conclude that all *maps were mental maps, that is, "subjective" to one degree or another."*

Lacking such field observers, I compared my sketch maps both to each other and to an arbitrarily selected standard,[12] *arbitrarily* selected because, unlike Lynch, I as a geosopher could *not* put consideration of the objectivity of air photos, maps, and diagrams aside.[13] Indeed the question lay at the heart of my dissertation, in which I was to conclude that *all* maps were mental maps, that is, "subjective" to one degree or another.[14]

The logic here was straight-forward. Among other things that Lynch's "proper 'objective' descriptions" could have referred to were state-of-the-art maps, but an introduction to the history of cartography had made it plain that over time state-of-the-art maps varied even more wildly than my sketch maps did. All maps varied, all the ones in people's individual and collective heads, and all the ones on paper. None "reflected" the "real" world. Apparently "factuality" was a state of mind. But if it was, then all maps *were* mental maps. I summarized this in a diagram that distinguished internal and external states of individual, consensual, and standard maps (Figure 1). No examples of "internal maps" can be displayed, if such maps even exist, which today I'm inclined to doubt. Whatever the form of the world in our heads, it is unlikely to take that of a map.[15] But Figure 2 displays a couple of individual sketch maps, and Figure 3 a pair of contrasting consensual maps. Consensual maps are shared by groups of like-minded, fellow-thinking people but are contested by others. Other consensual maps include those of contested voting districts, contested land claims, and the full range of counter maps. Standard maps exist in an abundance too great to even estimate: they're the maps you download at Google Maps, buy at gas stations, and consult in the atlas at the library.

In retrospect this scheme was breathtakingly naïve but I had yet to tumble to the idea of social construction.[16] Indeed it wouldn't be until 1979 that Bruno Latour and Steven Woolgar would publish *Laboratory Life: The Social Construction of Scientific Facts*; and more than twenty years before I'd

TYPE	EXTERNAL	INTERNAL
INDIVIDUAL MENTAL MAP	1. That external manifestation of the internal representation in the form of sketches, drawings et cetera.	1. That material in a person's head relating in any way to the spatial component of experience.
CONSENSUAL MAP	2. That map revealing a consensus of behavior, attitudes, beliefs, regarding space among a specified group and compiled from (1) above or other sources.	2. That material in a person's head which allows him to find an external consensual image personally useful or relevant.
STANDARD MAP	3. That map universally regarded as useful at a given point in time and space.	3. That material in a person's head allowing him to find a standard map personally useful or relevant.

Figure 1. This is Fig. 2.0 from my dissertation, I Don't Want To But I Will, *as published by the Clark University Cartographic Laboratory in 1973.*

pick up Steven Shapin and Simon Schaffer's *Leviathan and the Air-Pump* and really awake to the potential of the sociology of scientific knowledge for theorizing the standard map as a form of socially constructed geographic facts.[17] In the meantime I remained puzzled by what it could be, if *not* correspondence to the world, that compelled acceptance of the standard map.

To this puzzle Roland Barthes offered a couple of solutions. The first was his notion that there were forms of speech, that he called myths, that denied that they were forms of speech, and which therefore insisted on being taken … *as facts of the world*. Invariably these "facts" made the status quo out as natural, and therefore inevitable (this was Barthes famous *naturalization of the cultural*), and it struck me immediately that the standard map was just such a myth.[18] Barthes' analysis of myth turned on his semiotics, and semiotics turned out to be tailor-made for maps.[19] John Fels brought the semiotics of Umberto Eco and Algirdas Greimas to the table,[20] and together Fels and I were able to identify ten codes that either the map exploited or by means of which it was exploited (Figure 4).[21]

". . . the map insisted on being accepted not as a discourse about the world (which would be open to discussion, or a fight) but as the world . . ."

Although Fels and I didn't use the term "mask," our description of the actions of the presentational and rhetorical codes foreshadowed its use: we referred to Geological Survey topo quads as "dressing in the style of Science" as other maps "will dress in the style of Art. Or in the style of the Advertisement. Or in the Vernacular." "The rhetorical code," we wrote, "appropriates to the map the style most advantageous to the myth it intends to propagate."[22] It was when recapitulating this argument in "How Maps Work" that I concluded that it was through the presentational code "that the essential mask is donned, here that the map declares its impartiality, its neutrality, its objectivity."[23] That is, it was with the presentational code that the map insisted on being accepted not as a discourse *about* the world (which would be open to discussion, or a fight) but *as* the world itself (about which we could do nothing, which we could only accept), this is to say, as myth.

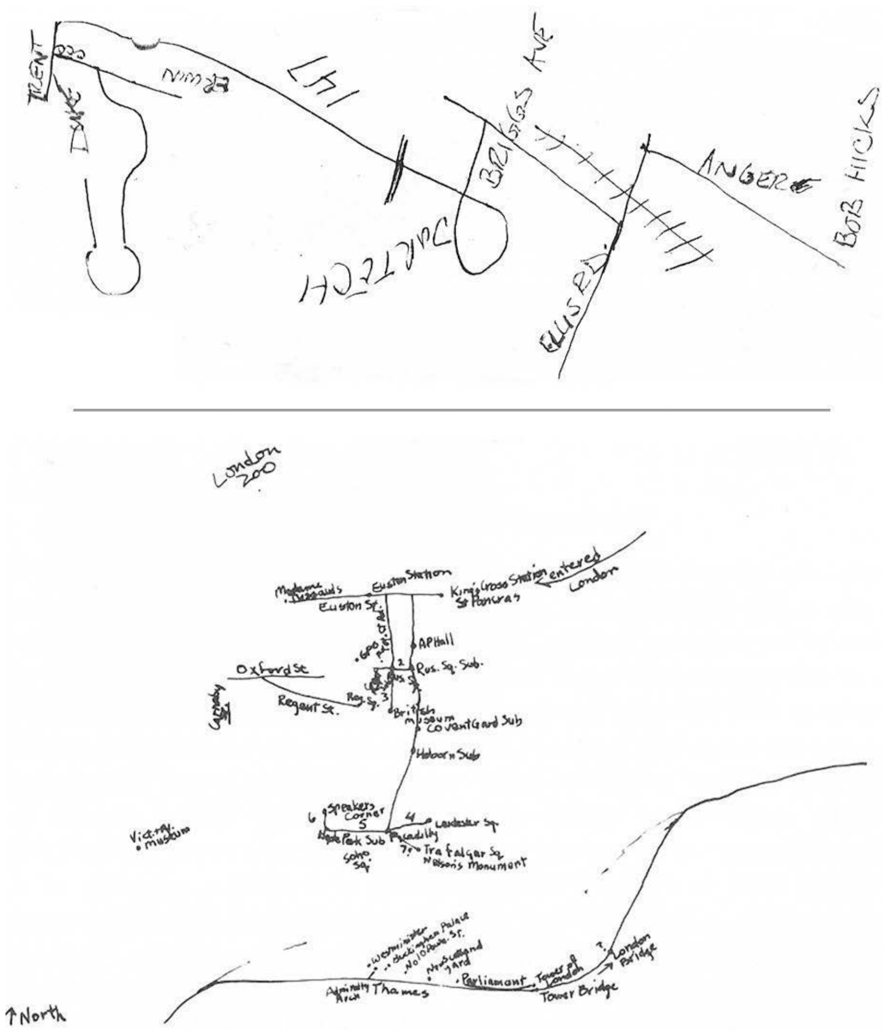

Figure 2. Here are a couple of sketch maps. Top is a sketch spontaneously made in 1993 by a security guard at Duke University to help us get to an auto repair shop in Durham. Below is a sketch of London I solicited from Janine Eber in the course of my dissertation research in 1970. I discuss the security guard's map in Denis Wood, Ward Kaiser, and Bob Abramms' Seeing Through Maps: Many Ways to See the World *(ODT, Amherst, 2006, pp. 2-4); and Janine's map in Denis Wood and Robert Beck's "Janine Eber Maps London: Individual Dimensions of Cognitive Imagery"* (Journal of Environmental Psychology 9*, 1989, pp. 1-26).*

Sealing the map's objectivity

Thus, by then I was able to see that the map *insisted on* being accepted, but not why it *was* accepted. That didn't happen until I started thinking about how people give and receive directions. "Think about what happens when you're stopped for directions," I asked in "What Makes a Map a Map":

> First you listen carefully to make sure you not only know the destination being sought but understand the problems involved in getting there. Then you say, "Sure, you turn left at the light, you go straight up the hill, and you'll see it at the top on your left," looking, as you say this, to your auditor for his or her comprehension. If your words don't "take," you try again. Ultimately you get the assent you need, the eager repetition, you make your confirmation, you get the satisfied nod, the thanks, and the satisfaction of watching the car make the appropriate

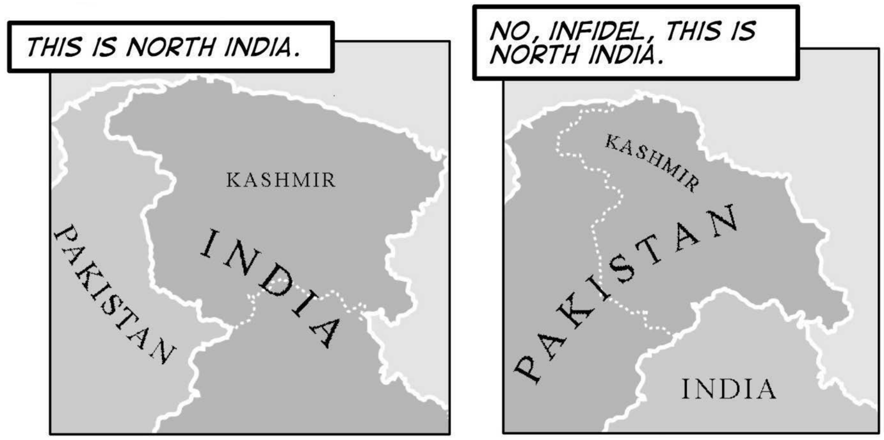

Figure 3. Here is a pair of contrasting consensual maps, showing the Pakistan-India-Kashmir region from, at left, an Indian perspective, and at right, a Pakistani perspective. John Krygier and I used these in our comic book, Ce n'est pas le monde*, that we presented last year to the 13th Annual Mini-Conference on Critical Geography in Columbus and at the NACIS annual meeting in Madison.*

> turn. But until the other has *assented*, your directions have not become objective (they have not become objects in the world), they are still too caught up in the personal (they are still too idiosyncratic to make much sense to the other); but in the interpersonal situation, the two of you keep trying until the directions ... *make mutual sense*. It is only after the driver (the other) has accepted the directions as sufficiently in the world – that is, has *sealed* with his nod their objectness (their objectivity) – that he will act on them. Does this sealing assure their accuracy? Not in the slightest. All of us give and take wrong directions all the time. The sealing only assures the status of the directions as *objects,* that is, as *objective,* in the world.[24]

". . . almost everything about the map looks to us for acceptance."

In the *trans*personal world where maps as more or less permanent, transmissible descriptions of territorial relations find their peculiar utility, this form of validation is unlikely if not inconceivable. Where mapmakers have not been smeared into institutional facelessness, or raveled into complicated layerings of multiple authorship, they live in another city or another century.

What is it, then, about a map produced in such a way, or at such a time, or in such a place that compels from us the attention (and usually the assent) that my auditor gave me? What is it about the assemblage of marks that ... *looks to us for acceptance?* In fact, almost everything about the map looks to us for acceptance. The title – what is a title but the map's *tilted head* asking, "*Get it? This is Asia ...*" – legend box, map image, text, illustrations, insets, scales, instructions, charts, apologies, diagrams, photos, explanations, arrows, decorations, color scheme, type faces, all are so many assurances, so many signs (*of gesture, eyes, cheek color, posture*), chosen, layered, structured, to frame a discourse, to achieve winning speech.[25] But as Fels and I had pointed out years earlier, the code works beyond these self-evident schemes of organization. The presentational code acts on the map as a whole, *at every level.* The mask covers more than the forehead, it infects everything, it determines the costumes, poses the body, picks the party. In the transpersonal universe, the mask is the unavoidable presence that at once *permits* the map to stand apart from the unknown heads and hands that brought it into being, but also that tells it *how* to do this. Without the mask the map collapses into a jumble of marks (it is not even a sketch), it is crumpled up, thrown away (*the directions are ignored*). *This*

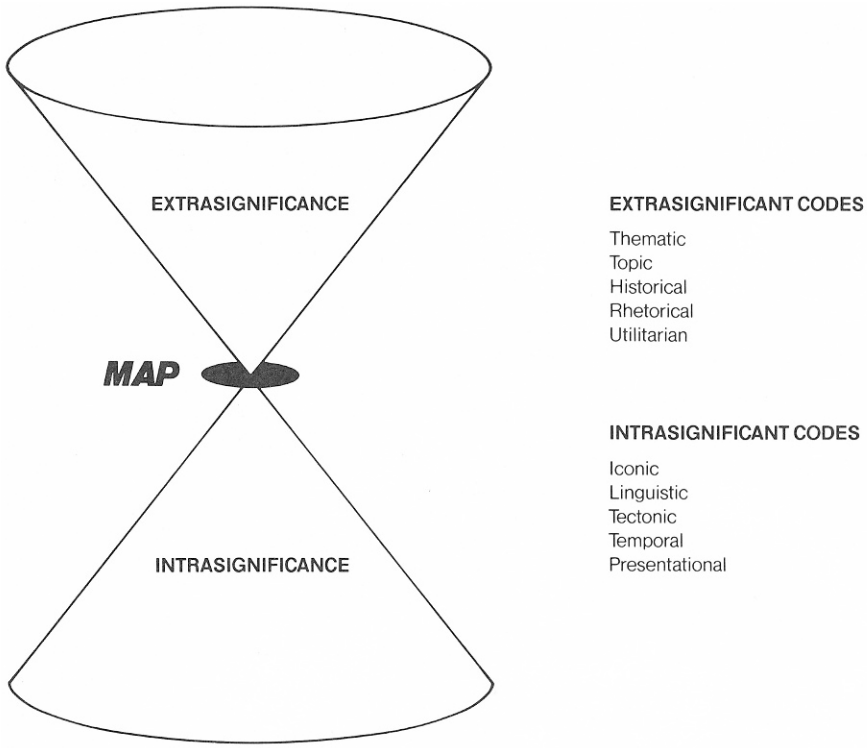

*Figure 4. John Fels and I saw the map as a focusing device between the domains of extra- and intra-significance: the map gathers up the constituent signs governed by the codes of intra-signification so that they will be able to act as signifiers in the sign-functions governed by the codes of extra-signification, which specified them in the first place. We first discussed these codes in our paper, "Designs on Signs: Myth and Meaning in Maps" (*Cartographica 23 *(4), 1986, pp. 54-103).*

is the mask no map goes without. *This* is the mask that *seals* the map, that provides the transpersonal validation that ensures the map's … *objectivity* (that is, its independence as an object in the world).

The mask seals the map in the transpersonal world

If we return, then, to the typology of maps I'd worked out for my dissertation twenty years earlier (Figure 1), we can see that only the external standard map unambiguously "stands apart from the heads and hands that brought it into being." The rest of the types are necessarily, essentially, or more or less *stuck*, either *in* the heads, or *to* the heads and hands responsible for them. This is self-evidently true of the internal maps. But it is hardly less true of external individual mental maps. In fact it is *precisely the subjectivity of experimental sketch maps that we value,* the *only* reason we solicit them. And it is more or less true of external consensual maps, more true as they are perceived to be "self-interested and biased" (that is, attached to their creators), and less true as the perception of their "objectivity" increases (of course the mask changes correspondingly). To put this in other words, only the external standard map wears the mask that no map goes without, and only the external standard map is what we are used to calling a map.

Nor can the mask be put on *after the fact*. This is because the mask is not merely, or even especially, the neat-line, legend, title, scale, and so on, but the way all of the marks – *all of them together* – have been orchestrated to achieve the map's appearance of independence, of being free of any maker, of being objective (and so mythic). For this reason neither an experimental sketch map nor a sketch map made in the throes of conversation (dependent on speech for its sealing) can wear the mask, and an attempt to put it on only produces the grotesque (Figures 5). To wear the mask the map would have to be redrawn from the beginning with the mask in mind.

Let me try to recapitulate the main points of this messy argument (I make no apologies: it's hard going). First, I'm arguing that maps are a discourse function of the type Barthes termed myth, that is, maps are images of the world that proclaim their objective neutrality, an important source of their authority.[26] Secondly, I'm arguing that the proclamation of their objective neutrality is *sealed* by an orchestration of marks carried out under the presentational and rhetorical codes, and I've called this orchestration "the mask *no* map goes without." Thirdly, I'm concluding, because they do not proclaim their objective neutrality (if anything, quite the contrary), that neither experimentally generated sketch maps nor sketch maps in general are maps. Not only do I feel that this conclusion is warranted, but I'm confident that the historical record supports it. People save maps. They take care of them, they horde them, they catalogue them, they pile them up in libraries. People throw sketch maps away. Of the huge number we might imagine has been made – that so many authors are so fond of describing being sketched in sand and snow and on scraps of paper – almost none remains. Those that haven't been blown away by the wind have been tossed in the waste basket.

"The sketch map comes into the world naked, "subjective" and expressive."

And why not? The effort to orchestrate the marks required to proclaim a map's objective neutrality is a demanding one. Because of this, maps are repositories of immense loads of horded knowledge, energy, ingenuity, craft, and labor. Consequently maps are precious. People everywhere recognize this and cherish maps because of it. Sketch maps embody little if any of this load and are therefore comparatively worthless. People everywhere recognize this too, and because they do, they throw sketch maps away. But the difference in value is epiphenomenal. It's their attitude that ultimately sets them apart. The sketch map comes into the world naked, "subjective" and expressive. The map comes masked, "objective" and mythic. "Myth," Barthes reminds us, "is always language robbery," stealing the ostensible subject of a map to naturalize *through it* something else, as the North Carolina highway map naturalized the state through its apparent interest in roads.[27] All primary expression can fall prey to myth, Barthes argued: "Nothing can be safe from myth. Myth can develop its second-order schema from any meaning."[28]

How map art takes the mask off

While no meaning can resist capture, it is possible to turn the table. Barthes suggested that "The best weapon against myth is perhaps to mythify it in its turn, and so to produce an *artificial myth*: and this reconstituted myth will in fact be a mythology. Since myth robs language of something, why not rob myth? All that is needed is to use it as the departure point for a third semiological chain, to take its signification as the first term of a second myth."[29] Since mythologies highlight the mythic character of myth, they rob myth of its "objectivity," that is, of its claim to represent the world: mythology peels off the mask of myth.[30] *This is precisely the tack most commonly taken by artists working with maps*.

It may be useful here to look again at the one art map Denil selected from the many I mentioned, *The World at the Time of the Surrealists*.[31] While I noted in a footnote that the artist of this widely reproduced map is unknown, it is actually not impossible to hazard a guess that it was the poet

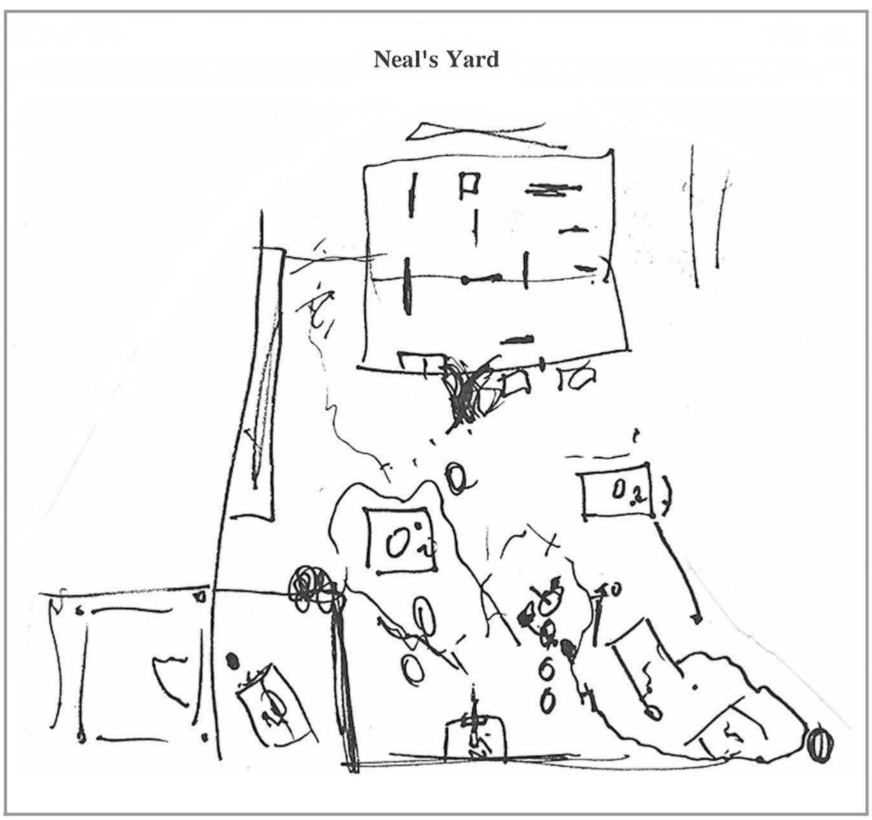

*Figure 5. At the top is a sketch of Neal's yard that Kelly spontaneously made to help me understand a game he and Neal had invented. Its independence was sealed by things we said to each other as he sketched, and by looks and gestures. Below, his sketch tries to put the mask on after the fact. It's merely grotesque. The sketch is the subject of my paper, "What Makes a Map a Map" (*Cartographica 30 *(2&3), 1993, pp. 81-86).*

Paul Eluard. At the time Eluard was the managing editor of *Le Surréalisme au Service de la Révolution* for whose pages the map had been originally intended, along with the rest of the contents of the issue of *Variétes* in which the map finally appeared; and, in fact, together with André Breton and Louis Aragon, Eluard edited this special issue of *Variétes*. Circumnavigating the globe in 1924, Eluard, joined by his wife Gala and Max Ernst, had spent time in Southeast Asia and the East Indies where he had been powerfully affected by the horrors of Dutch and French colonialism. Eluard recorded his route on a map, *Les Cinq Parties du Monde, Planisphère, Comprenant toutes les Possessions Coloniales*, a classic of the era that displayed on a Mercator projection, English possessions in yellow, French in pink, Dutch in orange, Italian in mauve, and so on.[32] This map must have presented an irresistible target to the increasingly anti-colonial Eluard who closely anticipated Barthes' method for mythologizing a myth: Eluard traced over the mythic *Cinq Parties* with its "*toutes les Possessions Coloniales*" and used it as the departure for a third semiological chain that erased not only (as is usually noted) the United States but *most of Europe* (of France only Paris survives); that radically increased the size of the South Sea islands that Eluard believed most capable of breaking the European hegemony; and that replaced the old equator with one that approximated the route of Eluard's circumnavigation. Personalized, Surrealized, the world map of colonial possessions had its pretense of representing the world stripped from it. Its status as myth had been made clear. The mask had been pulled from its face.

". . . it is hard to imagine the Surrealists exploiting the presentational code to connote trustworthiness or, for that matter, any other detested bourgeois value."

Where experimental and other sketch maps fail to put the mask on, *most art maps strip it off*.[33] Denil's presumption that he and artists like Eluard make maps the same way is like saying that they both use their hands to do so. It's true, but gormless. It ignores the towering divide between their attitudes toward the world. As Denil himself fully acknowledges, the maps Denil makes as a professional cartographer are as fully masked as the colonialist map that Eluard unmasked. I'm looking at the maps of the *Vilcabamba-Amboro Conservation Megacorridor*, *Current Status*, and *Ten-Year Outcomes* that Denil made as a cartographer for Conservation International.[34] These maps have fully exploited the potential of the presentational code to connote trustworthiness, and I have no doubt that they are the hard-won results of painstaking efforts at marshalling the best and most relevant data that can be brought to bear in the most powerful way on how best to mitigate threats to biodiversity in the region and the world.[35] Trust, however, was hardly an appeal Eluard would have been likely to make. Trustworthiness was never a value of interest to Surrealism. If anything, one would imagine the contrary to have been the case, that Eluard and his collaborators hoped first to have encouraged a kind of vertigo in anyone contemplating their map, a disorientation, a puzzlement, perhaps a dawning wonder. "We believe in a new underground counter culture," Werner Spies quotes a Surrealist declaration with reference to this map, one "that will disrupt History and break the ludicrous grip of Fact."[36] No, it is hard to imagine the Surrealists exploiting the presentational code to connote trustworthiness or, for that matter, any other detested bourgeois value.

Nor would trustworthiness seem to have been much on the mind of Mona Hatoum, whose 2003 *Map* I also discussed. Composed of a ton-and-a-half of clear glass marbles spread across a slick concrete floor, *Map* would seem almost the embodiment of *un*trustworthiness, not only shape-shifting with every change of light, but threatening to send flying anyone who would dare to step on it. Like Eluard, the Palestinian Hatoum – born to a people without a country – takes a mythic map as a point of departure for a third semiological chain which, as mythology, strips the myth from the map of the world and holds it up to ask whether it is a one we want to live by.[37] Although art maps do not enter the world naked as sketch maps do, neither do they enter it masked as maps. Rather they come with masks in hand, masks pulled from the face of maps they've unmasked. In so doing they join sketch maps on the same side of the great divide. On their side, open speech, claiming no more for itself than to be spoken. On the other, alienated speech proclaiming its trustworthiness and demanding to be taken as true.

Endnotes

1 Mark Denil, "Opinion Column/Denis Wood's article "Map Art," *Cartographic Perspectives 55*, Fall, 2006, pp. 4-5. My "Map Art" article appeared in *Cartographic Perspectives 53*, Winter, 2006, pp. 5-14.

2 The other articles in the Winter 2006 issue were Dalia Varanka's "Interpreting Map Art with a Perspective Learned from J. M. Blaut," kanarinka's "Art-Machines, Body-Ovens and Map-Recipes: Entries for a Psychogeographic Dictionary," John Krygier's "Jake Barton's Performance Maps: An Essay," and the catalogue of map artists I'd compiled. The issue was introduction by Denis Cosgrove's "Art and Mapping: An Introduction."

3 And this despite the fact that since Dalia Varanka discussed Warhol's map in her article, the Warhol map actually appeared twice in the issue, on pp. 19 and 72. As to the map's iconicity, see, among others, O. E. Clark, ed., *100 Maps: The Science, Art and Politics of Cartography Throughout History* (Salamander, London, 2005), pp. 188-189.

4 Steven R. Holloway, an untitled map from a series of four "reflecting on North 47º 56′ West 110º 30′ and on lines by Korzbsky," *Cartographic Perspectives 32*, 1999, cover.

5 See especially Barthes' long essay, "Myth Today," in his *Mythologies* (Hill and Wang, New York, 1970 [1957]), pp, 109-159.

6 Denis Wood and John Fels, "Designs on Signs: Myth and Meaning in Maps," *Cartographica, 23*(3), Autumn, 1986, pp. 54-103.

7 The Cooper-Hewitt's programming literature refers to this lecture, given October 5, 1992, as "The Power of Maps: Legitimation, Intimidation, Subjugation," but it was immediately published as "How Maps Work," *Cartographica, 29*(3&4), Autumn/Winter 1992, pp. 66-74.

8 This was the fifth Yale-Smithsonian Seminar on Material Culture. I gave the paper March 6, 1993 and it too was immediately published in *Cartographica, 30*(2&3), Summer/Autumn, 1993, pp. 81-86. For a related treatment also see the paper I wrote immediately afterwards, "The Fine Line Between Mapping and Mapmaking" (*Cartographica 30*(4), Winter 1993, pp. 50-60), where I push these ideas into an historical framework.

9 The critical paragraph was: "When I say 'objectivity' I want you to hear the root of the idea that is buried in '*object,*' that is, in *ob,* toward + *jacere,* to throw; or the even deeper idea implicit in the Indo-European root *ye,* that is, simply ... *throw.* Somehow the sketch map has not yet been sufficiently ... *thrown away,* is not yet the *jaculum* of *ejaculate,* is still too connected, is still too tied to the subject who created it. The kind of detachment I want to suggest is less that of *cool, indifferent,* or *disinterested,* and more that of the separation that gradually occurs as kids grows up, as they become less and less attached to their parents. We finally find ourselves saying, 'He's his own person now,' and, 'She's her own person now,' acknowledging – in the very enunciation

– that they weren't before. And the sketch maps still haven't broken away, are still too closely tied to their creators (to their parents). They haven't become objects on their own, they're not independent (they haven't become ... *people*)," "What Makes a Map a Map," ibid., p. 82. My idea of what "objectivity" means has continuously evolved over the years. My use of quotation marks throughout is intended to acknowledge this.

10 My dissertation was published in two volumes as *I Don't Want To, But I Will*, Clark University Cartographic Laboratory, Worcester, Massachusetts, 1973. Among others, Barbara Buttenfield worked on the graphics.

11 Kevin Lynch, *Image of the City*, MIT Press, Cambridge, 1960, p. 143. In my dissertation, I discuss this passage at length, pp. 497-501.

12 I called the first the Single Element Veridicality Analysis, and the second the Grid Analysis. In the first I locked all the sketch maps onto some common feature (say Euston Road) and examined variation among other features (Oxford Street, say, or the Thames). In the second I followed the path taken by Waldo Tobler in "Medieval Distortions: The Projections of Ancient Maps" (*Annals of the Association of American Geographers 66*, 1966, pp. 351-360).

13 My dissertation was self-consciously geosophical. "Geosophy" was coined by J. K. Wright in "*Terrae Incognitae*: The Place of Imagination in Geography" (*Annals of the Association of American Geographers 37*, 1947, pp. 1-15). Wright defined geosophy as the study of geography from any and all points of view: "… it covers the geographical ideas, both true and false, of all manner of people – not only geographers, but farmers and fishermen, business executives and poets, novelists and painters, Bedouins and Hottentots – and for this reason it necessarily has to do in large degree with subjective conceptions."

14 My use of quotation marks here is to reflect the continuous evolution in my thinking about the meaning of "subjective" too.

15 The evidence against maps in the head has been accumulating ever since the idea gained real currency in the 1960s. I really like the way Erik Jonsson puts it in his *Inner Navigation* (Scribner, New York, 2002): "Part of the trouble we have when we try to look at our cognitive map comes from the 'map' label, which is misleading. For our cognitive map is not a map: it does not look at all like a map. It would be better to call it our 'awareness of our familiar environment'" (p. 27).

16 See Ian Hacking's wonderful *The Social Construction of What?* (Harvard University Press, Cambridge, 1999) for an overview.

17 Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton University Press, Princeton, 1985). Their description of Boyle's program for establishing matters of fact through the social construction of assent, and the material, literary, and social technologies Boyle mobilized to do so (including the social construction of the open laboratory, the development of a self-consciously modest and functional style of writing, and the control of forms of discourse) are utterly convincing. Only the substitution of a few terms are required to turn their book into one about the social construction of geographic facts.

18 That maps worked to naturalize the status quo explained why maps changed over time, not due to any sort of "progress," but because the status quo was continually evolving.

19 Barthes' "Myth Today," was seminal, but his *Elements of Semiology* (Hill and Wang, New York, 1967 [1964]), *S/Z* (Hill and Wang, New York, 1974 [1970]), and *The Fashion System* (Hill and Wang, New York, 1983 [1967]) were also essential.

20 Critical here was Eco's *A Theory of Semiotics* (Indiana University Press, Bloomington, 1976). Greimas' writings were finally collected in *On Meaning: Selected Writings in Semiotic Theory* (University of Minnesota Press, Minneapolis, 1987 [1970-83]).
21 Wood and Fels, op. cit.
22 Ibid., pp. 70-71.
23 It's worth noting that "How Maps Work" opened with a list of *various* masks worn by different maps. It concluded with, "Each map wears its mask, yet beneath them all lies still another, the mask *no* map goes without" (p. 66).
24 "What Makes a Map a Map," op. cit., p. 82. Note that this idea of "objectivity" carries no burden of correspondence theory, nor is it concerned with bias or disinterestedness. Its sole concern is the object-status of the thing in the world. Jack Goody writes about this kind of objectivity as a general property of *writing*: "Writing puts a distance between man and his verbal acts. He can now examine what he says in a more objective manner" (in Goody's *The Domestication of the Savage Mind*, Cambridge University Press, Cambridge, 1977, p. 150). More recently David Turnbull has recast Goody's argument in an historically more subtle form in a discussion of Pacific navigation traditions (in Turnbull's *Masons, Tricksters, and Cartographers*, Routledge, London, 2000, pp. 151-153). This kind of objectivity is not quite, but close to, what Allan Megill writes about as "the dialectical sense of objectivity" in his "Four Senses of Objectivity;" that Johannes Fabian writes about as "ethnographic objectivity" in his "Ethnographic Objectivity Revisited: From Rigor to Vigor;" and that Andy Pickering describes in his "Objectivity and the Mangle of Practice," all three in the collection Megill edited called *Rethinking Objectivity* (Duke University Press, Durham, 1994).
25 Fels and I, in a text in press (*The Natures of Maps: Cartographic Constructions of the Natural World*, ESRI Press, Redlands, 2007) identify these aspects as the *paramap*, a term we've adopted from Gérard Genette's work on the paratext. See his *Paratexts: Thresholds of Interpretation* (Cambridge University Press, Cambridge, 1997 [1987]).
26 The essential authority remains the police power of the state.
27 The Barthes quote comes from his "Myth Today," op. cit., p. 131. In our forthcoming text, op. cit., Fels and I examine the naturalization of culture through the apparent interest of many maps in, among other things, earthquakes, ecosystems, the earth seen from space, parks, the range of pin oak trees, and so on.
28 "Myth Today," op. cit., p. 131.
29 Ibid., p. 135.
30 As I explained in my map art paper, this is most often made evident by the elimination of the phatic signage commonly associated with maps, though the opposite tack can be taken too and the signage can be exaggerated. The extreme here would be all phatic signage, none under the control of the topic or temporal codes, as in Lewis Carroll's well-known *Ocean-Chart* from *The Hunting of the Snark.*
31 *Le monde au temps des Surréalists*, published as a double-page spread in a special issue, *Le Surréalisme en 1929*, of the Brussels journal, *Variétes*, June 1929, pp. 26-27. This issue of *Variétes* was reprinted in 1994 in the Collection Fac-Similé from Didier Devillez Editeur, Brussels. Incidentally, in my original "Map Art" piece I claimed that the map was published without a neatline, as indeed Patrick Waldberg reproduced it in his *Surrealism* (Thames and Hudson, London, 1965, p. 24) and I reproduced it in *The Power of Maps* (Guilford, New York, 1992, p. 183).

This was an error. The map very much had a neatline in *Variétes*.

32 This map, *Les Cinq Parties du Monde, Planisphère, Comprenant toutes les Possessions Coloniales*, A Taride Editeur, 18-20 Boulevard St. Denis, Paris, with Eluard's route marked by himself in ink, is currently in the possession of the Musée d'art et d'historie, in Saint-Denis (Paris). While the conclusion that Eluard may have authored *Le monde au temps des Surréalists* is mine, the grounds for thinking so lie in the story put together by Robert McNab in his *Ghost Ships: A Surrealist Love Triangle* (Yale University press, New Haven, 2004). McNab reproduces *Les Cinq Parties* on p. 58, and *Le monde au temps des Surréalists* on p. 211, once again without the neatline.

33 Some art maps don't put the mask on. In fact map artists exploit a range of strategies, but none results in the mythic discourse characteristic of a map.

34 These can be found in *ESRI Map Book Vol. 17: Geography and GIS – Sustaining Our World*, ESRI Press, Redlands, 2002, p. 25. Details of the maps are online at www.esri.com/mapmuseum/mapbook_gallery/volume17/conservation12.html.

35 What Denil's maps naturalize is an idea of *nature under threat*. Fels and I devote a chapter to an analysis of this myth (in our text in press, op. cit.), which we see as one of eight different "natures" maps have helped to construct.

36 In his "Preface" to McNab's *Ghost Ships*, op. cit., p. ix. Spies is the world's reigning expert on Ernst.

37 In particular Hatoum's map strips away the pretense of institutional stability, the establishment of which is the principal goal of, among others, national mapping agencies.

Visualizing Method-Produced Uncertainty in Isometric Mapping

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Isometric mapping, while highly uncertain, continues to be a preferred mapping method for continuous data in many of the physical and social sciences. Isometric method-produced uncertainty refers to the various map representations that result when different methods and/or specifications are used in the mapping process. This paper examines ways to communicate the nature and magnitude of isometric method-produced uncertainty to map readers so that they are encouraged to be uncertain when it is warranted. As a case study, we consider an extensive set of plant hardiness zone maps that result when different interpolation methods and sampling resolutions operate on the same set of data. Our results show that slightly different choices in the mapping process can result in very different looking isometric maps, and suggest that the manifestations of method-produced uncertainty are not as systematic, or straightforward, as suggested by interpolation accuracy assessments. We then explore the use of two existing visualization techniques, flickering and transparency, to communicate the nature and magnitude of isometric method-produced uncertainty.

Key Words: Map uncertainty, isometric mapping, map animation, visualization

INTRODUCTION

The fact that one can never be certain about the precision or accuracy of maps, nor their underlying data, is inextricably bound to cartography. As is the case with any other communication medium, mapping is afflicted with misconceptions, misinterpretations, mistakes, and method-produced error. A great deal has been written and published about cartographic uncertainty, at times using synonyms such as accuracy, quality, error, and reliability (e.g., Buttenfield, 1993; Hunsaker et al., 2001; Hunter and Goodchild, 1996; MacEachren et al., 1998). Quite often, uncertainty is posed as not just an inherent product of map making, but as a 'quality' which has negative impact, and as an explanation for some of the frailties of maps. In that sense, uncertainty is an unavoidable byproduct of mapping geographic reality at scales that demand reduction in certainty, among other things. None of this is news to cartographers, but it may be a revelation to people who use our maps.

"Cartographic uncertainty exists as one of the costs we incur in map visualization, but map users are rarely encouraged to feel uncertain about the maps they view."

Cartographic uncertainty exists as one of the costs we incur in map visualization, but map users are rarely encouraged to feel uncertain about the maps they view. We often lecture students in our classes about map fallibilities, and we may write about numerical expressions of error or reliability. That said, it would be understandable if cartographers expected the public to have an inbuilt wariness of maps. However, this is probably not the case because map readers are not usually informed in an explicit way that maps have shortcomings that can't be entirely remedied. In the case of this research, we maintain that people who read maps are not normally instructed about the meaning of uncertainty, or how to under-

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stand uncertainty. The goal of this paper is to examine some possible ways to inform map readers visually about uncertainty using static as well as animated techniques.

Method-Produced Uncertainty in Isometric Mapping

Isometric mapping has a strong tradition and extensive history in the social and physical sciences, and is a preferred method for mapping distributions of continuous phenomenon measured with interval or ratio-scaled data (see Robinson, 1961). In isometric mapping, real data values, or control points, are used to develop a three dimensional surface that is visualized by two dimensional quantitative line symbols. While once a manual process, the majority of contemporary isometric maps are created using computer-based methods (Dent, 1999; see also Mulugeta, 1996). In automated interpolation, a continuous grid of data values is derived from a non-continuous distribution of control points. Following interpolation, isolines are placed according to specified intervals.

". . . the uncertainty associated with isometric mapping is exacerbated by the fact that the majority of data values shown on a map are estimated from a limited number of control points."

While all maps have uncertainty, the uncertainty associated with isometric mapping is exacerbated by the fact that the majority of data values shown on a map are estimated from a limited number of control points. Furthermore, isometric maps tend to be very unstable, with different isoline placement when different techniques or specifications are applied to the same set of control points (see MacEachren and Ganter, 1990). To date, most treatments of isometric uncertainty have focused on map error. For example, Morrison (1971) defined three sources of method-produced error in isarithmic mapping: (1) the number of control points used, (2) the distribution of those control points, and (3) the interpolation method. Similarly, Robinson et al. (1995) defined several additional sources of error relating to data quality, class interval assignment, and the implied accuracy of the mapping concept itself.

By isometric method-produced uncertainty, we mean the various map representations that can result when different methods or specifications are used to map a given set of data. We use the term uncertainty, rather than error, because the majority of locations on a statistically derived surface cannot be validated. Consequently, the amount of error on a particular map will never truly be known. We suggest that method-produced uncertainty is manifested in three different but related ways: (1) interpolation accuracy, (2) visual stability, and (3) information stability, as discussed below.

"We use the term interpolation accuracy in reference to the extent that an interpolated surface deviates from the original set of control points."

Interpolation Accuracy

We use the term interpolation accuracy in reference to the extent that an interpolated surface deviates from the original set of control points. The majority of research concerned with interpolation accuracy has focused on assessing different interpolation methods in light of statistical accuracy. These studies have used several techniques, such as cross-validation (Isaaks and Srivastava, 1989), true validation (Voltz and Webster, 1990), and a variety of summary statistics to evaluate the accuracy of interpolated surfaces. Some early studies include Morrison's (1974) assessment of various interpolation methods and Dubrule's (1984) comparison of splines versus kriging for estimating well depth. Other studies conducted by soil scientists were concerned with the accuracy of different interpolation methods for predicting soil characteristics, such as moisture capacity (Van Kuilenburg et al., 1982), pH (Laslett et al., 1987), and clay content (Voltz and Webster, 1990). More recently, Declerq (1996) evaluated the accuracy of several interpolation methods using control point distributions with very different characteristics. By and large, these studies have shown that kriging and inverse distance weighting (IDW) tend to minimize interpolation error, but that results will vary depending on the nature and distribution of control point data.

Visual Stability

Visual stability is related to the concept of map stability (Muehrcke, 1990). It refers to the extent that visually detectable differences are found between isometric maps when different interpolation techniques or specifications are applied to the same set of control points. Visual stability is based on the premise that greater variability is associated with greater uncertainty as to which map best portrays a particular geographic phenomenon. Visual stability is scale dependent because differences that are visible at a large scale may be virtually indistinguishable as scale becomes smaller. For example, MacEachren and Ganter (1990) compared the visual stability of isoline and three-dimensional fishnet patterning when different sampling resolutions are applied to the same set of data. They found that patterning with isoline representations tends to be much less stable than with fishnet representations, and suggested that climatologists might benefit from using an alternative visualization method for representing their data.

"Visual stability . . . refers to the extent that visually detectable differences are found between isometric maps when different interpolation techniques or specifications are applied to the same set of control points."

Information Stability

By information stability, we mean the extent that the information shown on an isometric map changes when different interpolation techniques or specifications are applied to the same set of data. Information stability is similar to visual stability, but is not scale dependent if information is extracted from the map using non-visual techniques. Information stability is especially important when isometric maps are used in a Geographic Information System (GIS) for vector overlay, for coding point locations, or when they are viewed using an Internet Mapping Server (IMS), where users may have the ability to view maps at inappropriately large scales. For example, if point is located over a data island that is not visible at an intended scale, the point will be coded according to that data island, despite its size or visibility.

Communicating Isometric Uncertainty

"By information stability, we mean the extent that the information shown on an isometric map changes when different interpolation techniques or specifications are applied to the same set of data."

Despite the ambiguities discussed above, isometric mapping continues to be a preferred mapping method for many physical sciences, particularly in the fields of climatology and meteorology (see Dibiase et al., 1994). Map makers seldom, if ever, convey the nature and magnitude of method-produced uncertainty to map users, and this is especially problematic when isometric maps are used as a primary analytic tool (see MacEachren and Ganter, 1990).

Summary statistics, such as Root Mean Square Error (RMSE), are typically used to communicate interpolation accuracy (USGS, 1997). However, a number of problems arise when a single summary statistic is used to communicate the uncertainty associated with a particular map. First, summary statistics do not indicate how uncertainty is distributed from place-to-place. For example, Shortridge (2001) noted that a single portion of a digital elevation model could account for the majority of error reflected in a summary statistic. Second, two maps generated from the same set of control point data can have similar accuracy values, but show very different patterning (Declerq, 1996). Even when control points are removed from the sample for subsequent validation, interpolation accuracy remains a statistically informed guess. Finally, summary statistics generally estimate the accuracy of an interpolated grid and do not necessarily account for uncertainty in isoline placement. Map users rely on the position of isolines to extract information, not on the gridded surface that has been evaluated.

Very few alternatives to summary statistics have been proposed to express method-produced uncertainty in isometric mapping. A notable exception includes Robinson et al.'s (1995) suggestion of using isoline smoothing to promote wariness about the accuracy of line placement. They discussed this technique in the context of conceptual error, or "the validity of the concept presented by the map" (Robinson et al. 1995:514-515). As an example, they considered an isometric map representing the distribution of mean temperature data and suggested that "Cartographers can overcome the effects of these errors and inconsistencies from one part of an isarithmic map to another by smoothing the isarithms" (Robinson et al. 1995:515). Also related, but not specific to isometric mapping, is van der Wel's (1993) use of sliders to visualize uncertainty thresholds for categorical boundaries via line width and blurring (see MacEachren 1995:443) and Hengl et al.'s (2004) visualization of interpolation uncertainty using different confidence thresholds.

"Given the reality of method-produced uncertainty in isometric mapping, it is important to understand this uncertainty, and to communicate its existence and extent to map users, especially if a map is used for analytic purposes, or to assist in policy decision-making."

Given the reality of method-produced uncertainty in isometric mapping, it is important to understand this uncertainty, and to communicate its existence and extent to map users, especially if a map is used for analytic purposes, or to assist in policy decision-making. And therein lies the challenge. Exactly how are we to present the notion and magnitude of isometric uncertainty to map users? How can we facilitate the appropriate use of the isometric maps that we make? The purpose of this research is to examine the use of existing visualization techniques for communicating isometric uncertainty in order to inform map readers about how to interpret a particular map. The techniques that we consider include (1) flickering and (2) transparency, as discussed below.

The technique of flickering, attributed to MacEachren (MacEachren et al., 1993), draws from the concept of alternating syntagms, where different attributes of the same place are alternately displayed in register (see Monmonier 1992). Flickering, as applied by MacEachren (1995), involves the use of non-temporal animation to alternate between two or more maps so that a map reader can consider multiple pieces of information simultaneously. As an example of how flickering can be used to communicate uncertainty, MacEachren (1995) considered dissolved nitrogen surfaces for the Chesapeake Bay over a six-year period. He suggested that for each month, maps can be generated using different interpolation methods and "when these flickering images are run in sequence as an animation, they should provide both a reliability assessment of maps at each time period, and a way to assess changes in pattern stability over time" (MacEachren 1995, 447). We use the technique of flickering in a similar way, that is, to assess and visualize uncertainty in isometric boundaries when different interpolation techniques are applied to the same set of data.

The technique of using transparency to communicate uncertainty draws from MacEachren's visual variable "focus" (MacEachren 1992), which he later described in terms of "clarity" (MacEachren 1995). MacEachren subdivided clarity into three visual variables, including crispness, resolution, and transparency. The term transparency, when used to visualize uncertainty, refers to a "fog" that differentially obscures the map theme based on data uncertainty (see MacEachren 1992:15). Rather than using a transparent fog to mask uncertain portions of a map, we use transparency as a technique to simultaneously display alternate isometric maps that result when different interpolation techniques and parameters are applied to the same set of data. In what follows, we apply these two techniques to see if they are useful for exploring and visualizing method-produced uncertainty in isometric mapping. First, however, it is necessary to investigate the various manifestations of isometric uncertainty for a particular set of data.

As a case study, we consider an extensive set of plant hardiness zone maps that result when different interpolation methods and sampling resolutions operate on the same set of control points. The most fundamental choices that affect the outcome of an isometric map are the selection of an interpolation method and gridding interval. Gridding interval refers to the distance separating nodes on an equally spaced grid used for interpolation. Kriging and IDW are considered here because they have been shown to perform better in terms of interpolation accuracy and are the most common methods used (see Lam, 1983).

"As a case study, we consider an extensive set of plant hardiness zone maps that result when different interpolation methods and sampling resolutions operate on the same set of control points."

Plant Hardiness Zones

Plant Hardiness zone maps, intended to assist the public in planting appropriate vegetation, are found in a variety of textbooks, growing manuals, and classrooms throughout North America. Currently, the most widely used plant hardiness zone map was issued in 1990 by the USDA (Cathey 1990), and uses isolines to divide hardiness zones according to average annual low temperatures. This map is similar to previous versions (e.g., USDA, 1960) that follow hardiness zone map conventions. These conventions include (1) the use of average low temperatures recorded by weather stations to define hardiness zones, (2) the use of ten plant hardiness zones based on isolines placed at 10˚ F intervals, and (3) the use of a spectral color scheme to distinguish between ordinal hardiness zone values. We recognize that the use of alternative methods, such as incorporating elevation data, might improve the accuracy of hardiness zone maps (see Veve, 1994). However, our intent is not to develop better methods for making hardiness zone maps, but rather, to investigate ways to explore and communicate method-produced uncertainty in hardiness zone maps that have been created using conventional means.

For this study, we consider average annual low temperature readings archived by the National Climatic Data Center for 4,799 weather stations located within the conterminous United States (Figure 1). The average annual low temperature readings are based on temperature extremes from 1990 to 2000, with the number of observations ranging from 2 to 11 years for individual weather stations. The positional accuracy of control points is limited to 0.01 degree latitude and longitude. The distance between control points, as determined by Delaney triangles, varies from 1.8 to 385.3 km, with spacing between control points generally being greater in the mountainous west. The mean distance between control points is approximately 46 km.

". . . a total of 354 plant hardiness zone maps were created . . ."

With these data, a total of 354 plant hardiness zone maps were created in Surfer 7 (Golden Software 1999): 177 maps using kriging, and 177 maps using IDW. For each interpolation method, all default options were accepted, with the exception of the gridding interval. The default option in Surfer 7 uses ordinary, point kriging, and considers all of the control point data for interpolating each grid node. The default option relies on a linear variogram model taking the following form (Golden Software, 1999):

$$\gamma(h) = C_0 + S \cdot h$$

where

$\gamma(h)$ is the semivariance
C_0 is the unknown nugget effect
S is the unknown slope
h is the lag distance

To solve for (h), C_0 and S are determined as follows:

$$S = \max\left[\frac{Var - G_{nn}}{D_{ave} - D_{nn}}, 0\right]$$

$$C_0 = \max\left[\frac{G_{nn} \cdot D_{ave} - Var \cdot D_{nn}}{D_{ave} - D_{nn}}, 0\right]$$

where:
D_{nn} is the average distance to the nearest neighbor
D_{ave} is the average inter-sample separation distance
G_{nn} is one half the averaged squared difference between nearest neighbors
Var is the sample variance

The IDW option in Surfer 7 defaults to a weighting power of 2, with no smoothing. Like kriging, all control points in the default option are considered for interpolating each grid node. The equation for IDW is as follows (Golden Software 1999):

$$Z_{new} = \frac{\sum \left(Z_i / d_i^{\,wt}\right)}{\sum \left(1 / d_i^{\,wt}\right)}$$

where:
Z_i is the control point z value
Z_{new} is the interpolated z value
d is the distance
wt is the weighting power

For each method, 177 interpolated grids were created, each employing a different gridding interval ranging from 100 km to 1 km (Table 1). From 100 km to 23.3 km, all possible intervals allowed by Surfer were used. A sample of grid sizes were selected at 1-km increments for gridding intervals smaller than 23 km, because using every possible interval after that point would have required an overwhelming amount of production time with very little gain in information. For each interpolated grid, an isometric map was made in Surfer following plant hardiness zone map conventions.

Exploring Method-Produced Uncertainty in Plant Hardiness Zone Maps

As discussed at the outset, method-produced uncertainty in isometric maps is manifested in at least three different but related ways, including

Figure 1. Location of 4,799 weather stations considered for plant hardiness zones.

interpolation accuracy, visual stability, and information stability. Here, we explore method-produced uncertainty in plant hardiness zones given different choices in interpolation method and gridding interval.

Interpolation Accuracy

We evaluated the accuracy of each interpolated grid by computing RMSE values based on the difference between predicted and known temperatures for each of the 4,799 control points. RMSE values report the standard deviation of residuals (the difference between known and predicted values), and provide an estimate of how well an interpolated grid corresponds to the data used to create it. While a variety of summary statistics have been used to evaluate interpolation accuracy, we chose RMSE because it is relatively easy to compute, and significantly easier to understand than other methods.

"We evaluated the accuracy of each interpolated grid by computing RMSE values based on the difference between predicted and known temperatures for each of the 4,799 control points."

RMSE is derived using the following equation:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}\left(y_i - y_j\right)}{N-1}}$$

where:

y_i is the predicted temperature value

y_j is the known temperature value

N is the number of sample points

Table 1 reports the RMSE values generated for each interpolated grid. RMSE values decrease in a systematic, non-linear manner, with interpolation accuracy decreasing more rapidly as gridding intervals become finer (Figure 2). Figure 3 shows the distribution of residuals for selected gridding intervals, further emphasizing this trend.

There are several ambiguities in using this method to estimate interpolation accuracy. Because kriging and IDW, as applied here, operate as

Frame #	Gridding Interval (m)	IDW RMSE (ºF)	Krig RMSE (ºF)	Frame #	Gridding Interval (m)	IDW RMSE (ºF)	Krig RMSE (ºF)	Frame #	Gridding Interval (m)	IDW RMSE (ºF)	Krig RMSE (ºF)
1	100766	3.37	3.31	61	43782	2.56	2.25	121	27923	2.06	1.75
2	98622	3.38	3.30	62	43320	2.57	2.26	122	27755	2.04	1.73
3	96567	3.43	3.34	63	42918	2.57	2.22	123	27590	2.01	1.71
4	94596	3.32	3.23	64	42525	2.53	2.22	124	27427	1.99	1.70
5	92704	3.32	3.15	65	42138	2.52	2.22	125	27266	2.03	1.71
6	90887	3.36	3.22	66	41758	2.50	2.20	126	27106	1.99	1.68
7	89139	3.31	3.21	67	41386	2.54	2.23	127	26949	1.97	1.67
8	87457	3.32	3.26	68	41019	2.52	2.21	128	26793	1.95	1.65
9	85837	3.25	3.11	69	40660	2.44	2.14	129	26639	1.96	1.66
10	84277	3.25	3.14	70	40306	2.47	2.16	130	26487	1.96	1.66
11	82772	3.25	3.14	71	39959	2.48	2.18	131	26336	1.96	1.66
12	81320	3.19	3.07	72	39617	2.46	2.13	132	26187	1.95	1.65
13	79918	3.19	3.07	73	39281	2.44	2.12	133	26040	1.93	1.64
14	78563	3.17	3.02	74	38951	2.44	2.11	134	25895	1.91	1.62
15	77254	3.13	2.97	75	38627	2.40	2.10	135	25751	1.91	1.61
16	75987	3.11	2.99	76	38307	2.42	2.11	136	25609	1.93	1.63
17	74762	3.13	2.98	77	37993	2.39	2.11	137	25468	1.92	1.63
18	73576	3.12	2.96	78	37684	2.38	2.06	138	25329	1.94	1.65
19	72425	3.06	2.89	79	37381	2.38	2.07	139	25191	1.91	1.62
20	71311	3.02	2.84	80	37081	2.36	2.07	140	25055	1.89	1.59
21	70230	3.06	2.88	81	36787	2.34	2.04	141	24920	1.88	1.59
22	69182	3.08	2.92	82	36497	2.34	2.03	142	24787	1.87	1.59
23	68165	3.03	2.85	83	36212	2.34	2.02	143	24655	1.88	1.58
24	67177	3.02	2.83	84	35932	2.34	2.02	144	24525	1.91	1.61
25	66217	3.02	2.81	85	35655	2.32	2.01	145	24396	1.88	1.57
26	65285	2.99	2.80	86	35383	2.31	1.99	146	24268	1.84	1.56
27	64378	3.01	2.80	87	35115	2.30	1.98	147	24141	1.83	1.57
28	63496	2.94	2.72	88	34851	2.33	2.00	148	24016	1.83	1.55
29	62638	2.97	2.73	89	34591	2.34	2.00	149	23893	1.84	1.55
30	61803	2.96	2.74	90	34335	2.29	1.98	150	23770	1.82	1.54
31	60990	2.89	2.68	91	34082	2.28	1.96	151	23649	1.83	1.56
32	60197	2.89	2.65	92	33833	2.28	1.97	152	23525	1.82	1.54
33	59426	2.88	2.64	93	33588	2.26	1.94	153	23410	1.80	1.52
34	58673	2.86	2.62	94	33347	2.25	1.93	154	23292	1.78	1.50
35	57940	2.87	2.63	95	33108	2.24	1.93	155	22946	1.81	1.53
36	57225	2.84	2.59	96	32874	2.20	1.88	156	21967	1.73	1.45
37	56527	2.85	2.61	97	32642	2.21	1.89	157	20973	1.66	1.41
38	55846	2.85	2.60	98	32414	2.23	1.91	158	19979	1.61	1.37
39	55181	2.80	2.56	99	32189	2.22	1.89	159	18996	1.54	1.31
40	54532	2.81	2.56	100	31967	2.19	1.86	160	17966	1.46	1.24
41	53898	2.80	2.55	101	31784	2.18	1.87	161	16978	1.41	1.22
42	53278	2.81	2.56	102	31532	2.21	1.89	162	15983	1.33	1.16
43	52637	2.78	2.52	103	31319	2.18	1.86	163	15000	1.28	1.12
44	52081	2.75	2.51	104	31109	2.12	1.80	164	14003	1.18	1.06
45	51147	2.69	2.45	105	30901	2.15	1.82	165	12983	1.09	0.99
46	50936	2.69	2.43	106	30696	2.15	1.85	166	12008	1.04	0.95
47	50383	2.70	2.43	107	30495	2.15	1.83	167	11010	0.95	0.89
48	49841	2.73	2.47	108	30295	2.14	1.81	168	9989	0.86	0.83
49	49311	2.70	2.43	109	30098	2.08	1.78	169	9000	0.73	0.73
50	48792	2.65	2.35	110	29904	2.12	1.80	170	8005	0.64	0.67
51	48283	2.62	2.35	111	29713	2.13	1.82	171	7001	0.54	0.60
52	47786	2.67	2.41	112	29523	2.14	1.83	172	5996	0.46	0.54
53	47289	2.68	2.39	113	29336	2.11	1.79	173	5000	0.35	0.45
54	46820	2.66	2.35	114	29152	2.09	1.76	174	3999	0.26	0.37
55	47786	2.63	2.34	115	28970	2.08	1.78	175	3000	0.16	0.27
56	47289	2.63	2.33	116	28790	2.06	1.76	176	1999	0.09	0.19
57	45443	2.65	2.38	117	28612	2.00	1.71	-	1000	0.02	0.10
58	45002	2.62	2.32	118	28437	2.05	1.74	-	500	0.01	0.05
59	44569	2.57	2.27	119	28263	2.06	1.75				
60	44199	2.58	2.27	120	28092	2.04	1.73				

Table 1. RMSE values for kriging and IDW by gridding interval and animation frame number. The animation frame number refers to individual frames in Animations 1-3 (see Animations 1-3; Figure 2.)

exact interpolators, grid nodes occurring at the same location as control points will be assigned the same value as the control point (Lam, 1983). If a substantial number of grid nodes co-occur with control points, RMSE values will tend to underestimate interpolation error. While RMSE does not provide an exact indication of interpolation accuracy, fundamental

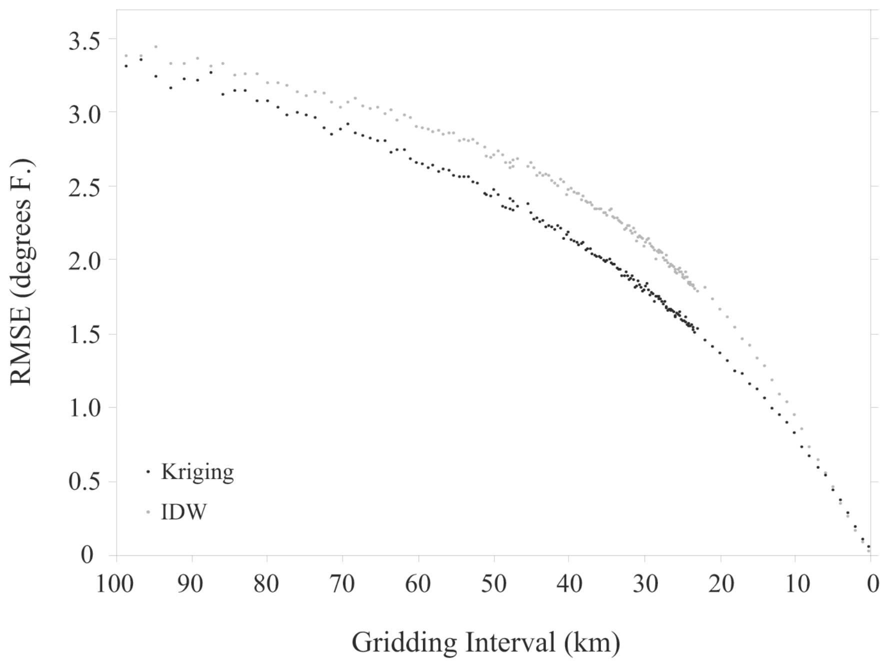

Figure 2. Scatter plot showing relationship between RMSE and gridding interval for kriging and IDW.

problems exist with all accuracy statistics that rely on the same set of data used for interpolation.

To see if the differences in interpolation accuracy between kriging and IDW are statistically significant, we performed a series of two-sample t-tests. The t-tests evaluate the null hypothesis that average error, or mean deviation, between the Kriging and IDW grid is similar. By average error, we mean the average difference between known values and predicted values on the interpolated surface. Figure 4 is a scatter plot diagram showing the t-test results by gridding interval and significance (p) value. The t-statistics report the strength of the difference in average error between Kriging and IDW. The graph shows that the strength of differences increases from 100 km to ~30 km, and then decreases dramatically until ~11 km. From 10 km to 1 km, the strength of difference rises dramatically. At the 0.05 significance level, these differences are statistically significant for gridding intervals ranging from 72 km to 14 km and gridding intervals ranging from 8 km to 1 km. The difference in average error is not statistically significant for gridding intervals ranging from 100 km to 73 km and for gridding intervals ranging from 13 km to 9 km. As can be seen in Figure 4, the majority of paired gridding intervals show statistically significant differences between Kriging and IDW interpolations.

Although statistical significance provides a numerical measure of differences, it does not provide information about how map users may cognize visual patterns shown on isometric maps. Although it is beyond the scope of this research, it would be useful, for example, to empirically examine human responses to the visual effects of different gridding intervals. In this sense, subjects could compare frames for detectable differences they may see. The results of such an experiment could then be used in conjunction with the RMSE and t-test results to present both a statistical and cognitive view of isometric map patterns.

"Although statistical significance provides a numerical measure of differences, it does not provide information about how map users may cognize visual patterns shown on isometric maps."

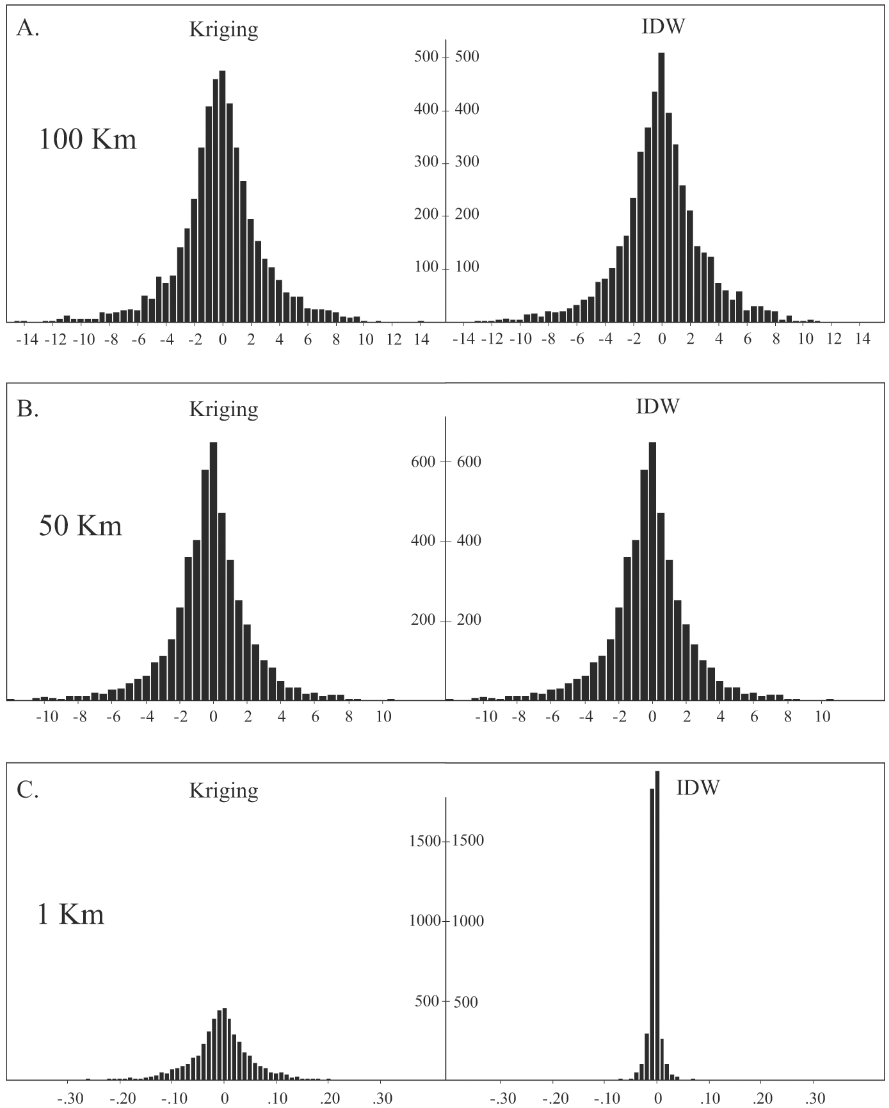

Figure 3. Distribution of the residuals (difference between predicted and observed values for each of the 4,799 weather stations) used for calculating RMSE for selected gridding intervals. a) Gridding interval is 100km. b) Gridding interval is 50 km. c) Gridding interval is 1 km.

Visual Stability

We display and evaluate visual stability in plant hardiness zones using the techniques of flickering and transparency. First, a non-temporal animation was created using Flash MX (Macromedia Corp. 2002) showing the hardiness zone boundaries for each interpolation method by gridding interval (Animations 1-3 [http://www.nacis.org/index.cfm?x=24]). The sequence is separated into three animations because of excessive file size. Compression was not used because we did not want to alter the original line geometry as determined by Surfer. The interface provides basic controls to play, stop, pause, and advance the animation sequence. We evaluated visual uncertainty by viewing the animation on a computer monitor at a scale of ~1:22,000,000, paying specific attention to line movement as gridding intervals decrease. Using this technique, visual uncertainty is not quantifiable, but we found it to be quite effective for (1) showing the variability in hardiness zone boundaries, and (2) for determining the gridding interval at which variability is no longer visible.

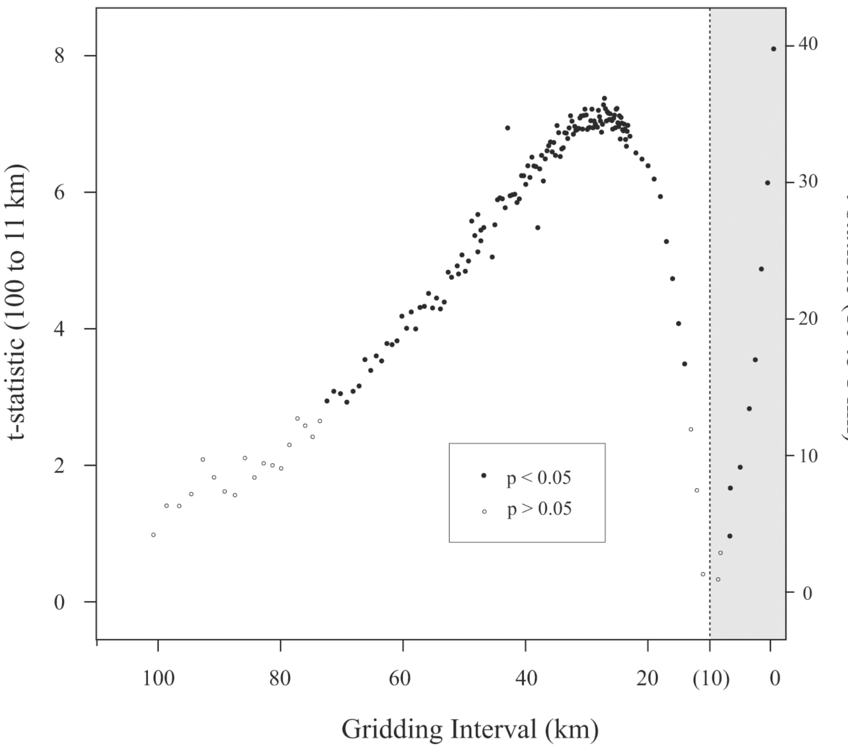

Figure 4. Scatter plot showing the result of 177 t-tests used to evaluate the null hypothesis that average error (difference between predicted and known values for 4,799 control points) is statistically similar for kriging and IDW when comparable gridding intervals are employed. The y-axis reports the t-statistic, or strength of difference between average error. The scale on the left indicates the t-statistic for gridding intervals ranging from 100 km to 11 km (white area), while the scale on the right indicates the t-statistic for gridding intervals ranging from 10 km to 1 km (gray area). Solid point symbols indicate a statistically significant difference, whereas circles indicate that there is not a statistically significant difference (● = 0.05).

The animations show that hardiness zone boundary variability is extreme for larger, and perhaps unrealistic, gridding intervals. For larger gridding intervals, boundaries shift dramatically and chaotically, even when similar gridding intervals are employed in the interpolation process. At a scale of ~1:22,000,000, stability for both interpolation methods occurs at a gridding interval of ~10 km. Variability in boundary placement does occur when finer intervals are employed, but this variability is difficult to see at this scale of observation.

The animation shows boundary variability between sequential gridding intervals, but it is not useful for assessing boundary differences that occur out of the animation sequence. Figures 5 and 6 show a variety of hardiness zone boundaries for selected portions of the animation sequence simultaneously. Thick boundaries imply greater uncertainty for hardiness zone assignment whereas thinner boundaries imply less uncertainty for that particular portion of the map. We found this method to be useful for assessing boundary variability, but less useful for detecting the differential occurrence of data islands.

"We found [flickering] to be useful for assessing boundary variability, but less useful for detecting the differential occurrence of data islands."

Information Stability

Information stability was assessed by recording the variability in hardiness zone assignment for 68 sample points by interpolation method and gridding interval. The sample includes capital cities within the 48 conterminous states, as well as 20 additional point locations. The location of capital cities was determined according to coordinates provided by the

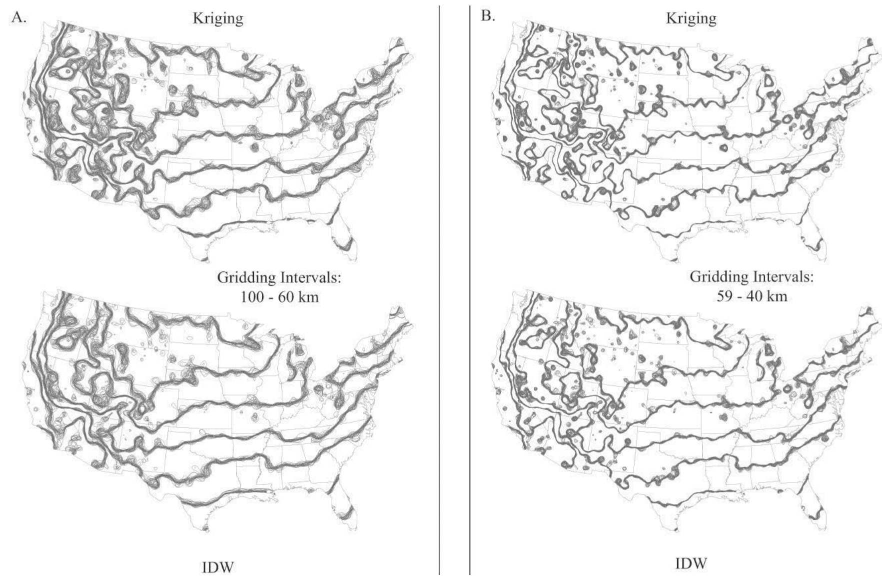

Figure 5. Composite maps showing the variability in hardiness zone boundaries for kriging and IDW for selected portions of the animation sequence (see Animations 1-3). Greater boundary width indicates greater method-produced uncertainty. a) Gridding intervals from 100-60 km. b) Gridding intervals from 59-40 km.

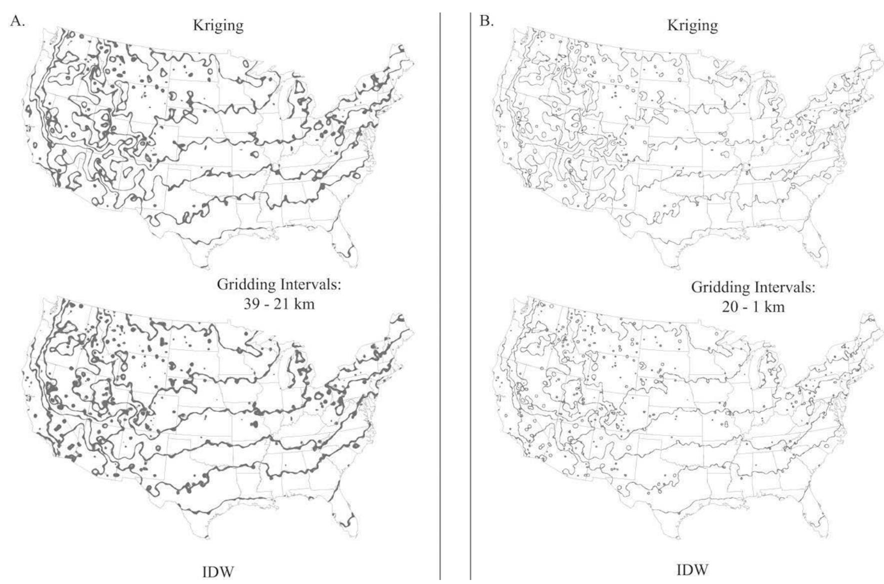

Figure 6. Composite maps showing the variability in hardiness zone boundaries for kriging and IDW for selected portions of the animation sequence (see Animations 1-3). Greater boundary width indicates greater method-produced uncertainty. a) Gridding intervals from 39-21 km. b) Gridding intervals from 20-1 km.

National Atlas of the United States (USGS, 2006). Because all capital cities fall within 10 km of the control points, 20 additional sample points were chosen based on their distance from control points, with 5 points selected at distance ranges of 10-30km, 30-50km, 50-70km, and >70km.

The plant hardiness zone that was assigned to each sample point was assessed for all 354 maps. These data were used to calculate hardiness zone changes as gridding interval becomes finer. By zone change, we mean a shift in zone assignment between sequential animation frames. For example, if a sample point was assigned zone 4, then zone 5, and then zone 4; two zone changes would be recorded. If a sample point was assigned zone 4, then zone 5, then zone 5; only one zone change would be recorded.

Of the 68 sample points, 24 (35%) changed zones at least once, 16 (24%) changed zones over three times, and 5 (7%) changed zones over fifty times. Interestingly, Pierre, South Dakota changed zones 120 times, and Salt Lake City, Utah changed zones 90 times (Figure 7a). Table 2 shows the number and percent of control points that changed zones at least once according to 10-frame groupings. Figure 7b shows that the information contained in the plant hardiness zone maps tends to become more stable as gridding interval decreases, but also suggests that this relationship is not necessarily straightforward or predictable until stability occurs.

". . . Pierre, South Dakota changed zones 120 times, and Salt Lake City, Utah changed zones 90 times. "

Discussion

Our results shed light on some interesting trends regarding the behavior of Kriging versus IDW for plant hardiness zone boundaries when different gridding intervals are employed in the interpolation process. With respect to interpolation accuracy, as indicated by RMSE values, kriging appears to perform more accurately at coarser intervals, while IDW tends to perform slightly better at intervals finer than 9 km (see Figure 2, Table 1). This difference, however, is minor, with the greatest difference in RMSE being 0.35˚ F at a gridding interval of 42.9 km (see Figure 4 for significance).

In terms of visual uncertainty, for both kriging and IDW, hardiness zone boundaries tend to stabilize at a gridding interval of ~10 km when the maps are viewed at a scale of ~1:22,000,000. Further research is necessary to know if "average" map viewers would consider the maps to be visually stable when gridding intervals of less than 10 km are employed. Furthermore, this information could be used to explore the relationship between

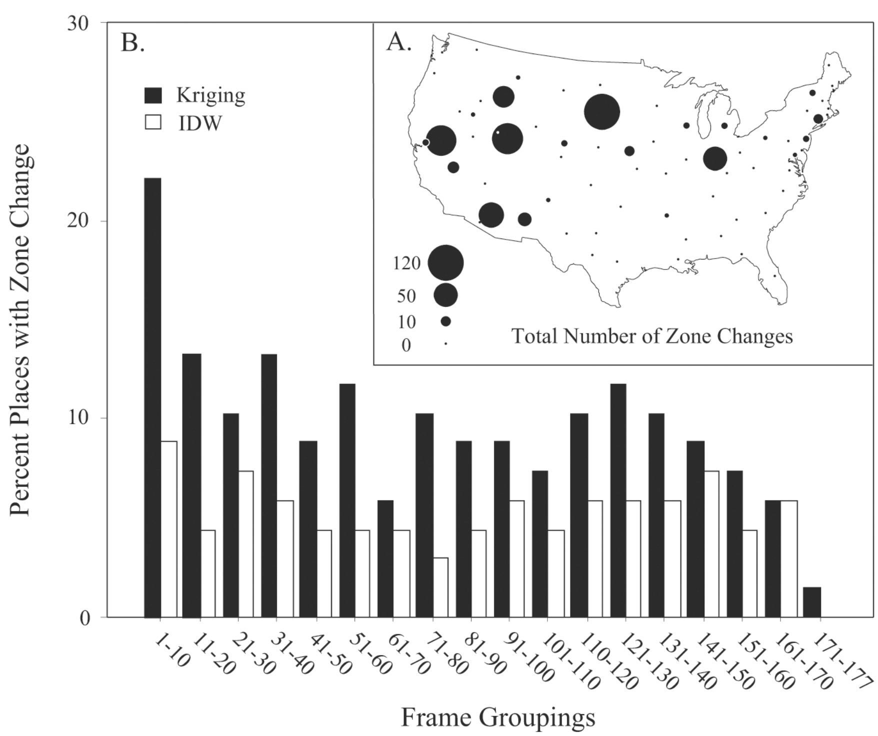

Figure 7. Information stability of hardiness zone assignment for 68 sample locations. (a) Total number of zone changes. (b) Percent places having zone changes by interpolation method according to 10-frame groupings in the animation sequence (see Animations 1-3).

Animation Frame #	Gridding Intervals (km)	Kriging Zone Changes		IDW Zone Changes	
		Number	Percent	Number	Percent
1-10	100.8 - 84.3	15	22	6	9
11-20	82.8 - 71.3	9	13	3	4
21-30	70.2 - 61.8	7	10	5	7
31-40	61.0 - 54.5	9	13	4	6
41-50	53.9 - 48.8	6	9	3	4
51-60	48.3 - 44.2	8	12	3	4
61-70	43.8 - 40.3	4	6	3	4
71-80	40.0 - 37.1	7	10	2	3
81-90	36.8 - 34.3	6	9	3	4
91-100	34.1 - 32.0	6	9	4	6
101-110	31.8 - 29.9	5	7	3	4
110-120	29.7 - 28.1	7	10	4	6
121-130	27.9 - 26.5	8	12	4	6
131-140	26.3 - 25.0	7	10	4	6
141-150	24.9 - 23.7	6	9	5	7
151-160	23.6 - 18.0	5	7	3	4
161-170	17.0 - 8.0	4	6	4	6
171-180	7.0 - 1.0	1	1	0	0

Table 2. Number and percent of 68 sample locations having zone changes by 10-frame groupings in the animation sequence (see Animations 1-3; Figure 6).

interpolation accuracy (as expressed as RMSE) and visual stability. While empirical studies with human subjects are outside the scope of this paper, such research should be explored in the future. In terms of information content, IDW appears to produce much more stable boundaries than Kriging. The overall difference in patterning provided by IDW and Kriging further emphasizes the tendency for IDW to create isolated data islands when all control point data are used for interpolation, a trend noted by Slocum (1999).

". . . there is no clear relationship between the average distance between control points (~46 km) and the gridding interval at which visual stability tends to occur (~10 km)."

Interestingly, there is no clear relationship between the average distance between control points (~46 km) and the gridding interval at which visual stability tends to occur (~10 km). Furthermore, the sample points that showed the greatest information instability do not necessarily take place near a relatively consistent isoline boundary. For example, Salt Lake City, Utah and Pierre, South Dakota have a high number of zone shifts because isolated data islands appear and disappear repeatedly, even when only slightly different gridding intervals are employed.

"The relationship between method-produced uncertainty and gridding interval is not as straightforward as that suggested by the systematic decrease in RMSE values shown in Figure 2."

The results reported here support the assertion that summary statistics, as used for evaluating interpolation accuracy, are not sufficient for characterizing the uncertainty associated with isometric mapping (see Declerq, 1996). When we applied a gridding interval of 9 km, kriging and IDW produced interpolated grids having nearly identical RMSE values (~0.73). The patterning shown in the two isometric maps, however, is quite different (e.g., Mohave Desert; Figure 8). This holds true even when the same interpolation method is applied with different gridding intervals, especially when gridding intervals are relatively large. For example, when kriging is applied at intervals of 100 km and 99 km, dramatically different maps result, but RMSE values differ by only 0.006° F. The difference between these two maps may seem trivial if only RMSE is considered.

The relationship between method-produced uncertainty and gridding interval is not as straightforward as that suggested by the systematic

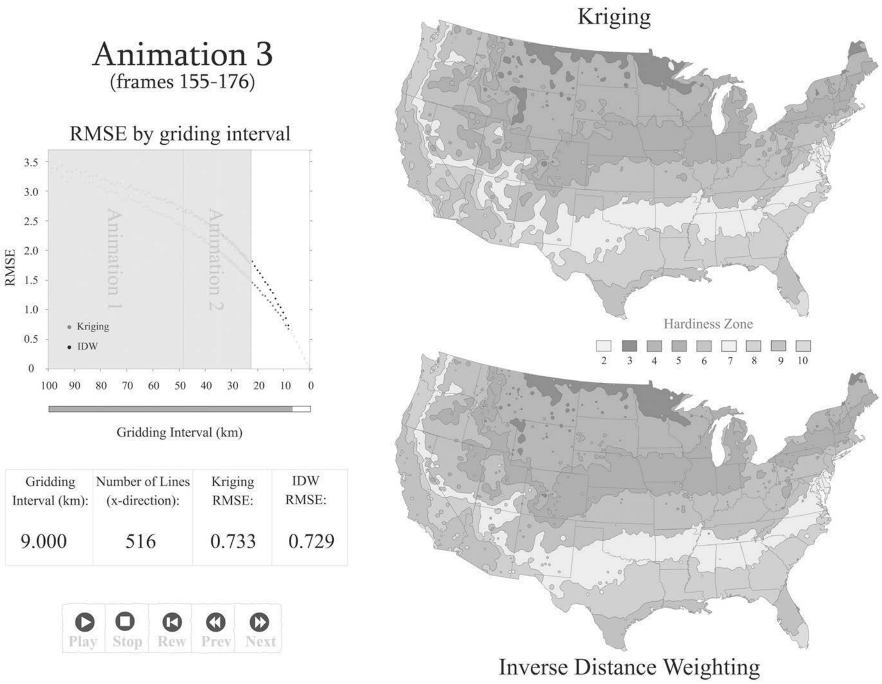

Figure 8. Screen capture of frame 169 of Animation 3 showing the difference in patterning for kriging and IDW when RMSE values are nearly identical. (see page 74 for color version)

decrease in RMSE values shown in Figure 2. While finer gridding intervals tend to be associated with greater information stability, the percent of zone changes fluctuates chaotically until stability occurs (see Figure 7, Table 2). For example, when IDW is employed, a greater number of sample points demonstrate zone change at intervals ranging from 24.9-23.7 km (Animation Frames 141-150), than at intervals ranging from 82.8-71.3 km (Animation Frames 11-20).

Given these results, we might naturally recommend that cartographers employ the smallest gridding interval possible for interpolation so that more stable isometric maps will result. The fact that kriging and IDW show stable but very different representations of hardiness zone boundaries at fine gridding intervals supports the assertion that stability does not necessarily equal truth (but see MacEachren, 1995; Muehrcke, 1990). Moreover, changes in a variety of other parameters, such as search sector size, weighting exponent, or semi-variogram model, may produce even different patterning when fine gridding intervals are used in the interpolation process. Our point is that no single isometric map will necessarily best represent hardiness zone boundaries because isometric maps contain inherent properties that make it difficult to verify a map's true accuracy. Rather than attempting to make a single best hardiness zone map, we focus on communicating the nature and magnitude of hardiness zone uncertainty by showing map readers a variety of reasonable hardiness zone maps, as discussed below.

". . . no single isometric map will necessarily best represent hardiness zone boundaries because isometric maps contain inherent properties that make it difficult to verify a map's true accuracy."

Communicating Method-Produced Uncertainty in Plant Hardiness Zones

We examine the use of flickering and transparency for communicating method-produced uncertainty in plant hardiness zones in order to examine their effectiveness when applied to our set of data. First, we created a non-temporal animation that flickers a variety of reasonable hardiness zone maps (Animation 4 [http://www.nacis.org/index.cfm?x=24]; Figure 9). Our intention is to allow map users to differentiate between hardiness zone patterning that is method-produced and hardiness zone patterning that is data-produced. To assemble the animation, we chose 11 hardiness zone maps for each interpolation method. The animation shows hardiness zone maps from every tenth frame of the original animation sequence (Animations 1-3), with gridding intervals ranging from 25-54 km. Controls are included to allow users to toggle between the kriging and IDW animated sequences. Map users are not allowed to stop the animation so that more confidence cannot be placed in any single hardiness zone map.

While we found flickering to be a very effective technique for visualizing isometric uncertainty, this technique requires viewing the map on a computer screen. As an alternative to flickering, we explore the use of transparency for displaying several hardiness zone maps simultaneously. Figure 10 is a composite of 354 plant hardiness zone maps, half produced using kriging, and the other half using IDW. The composite map was created by stacking all 354 plant hardiness zone maps, deleting polygon outlines, and displaying each map at a 99% transparency. The premise behind this application of transparency is that a mixture between colors along the spectral sequence relates to method-produced uncertainty. Colors that do not deviate from the conventional plant hardiness zone color scheme

"The composite map was created by stacking all 354 plant hardiness zone maps, deleting polygon outlines, and displaying each map at a 99% transparency."

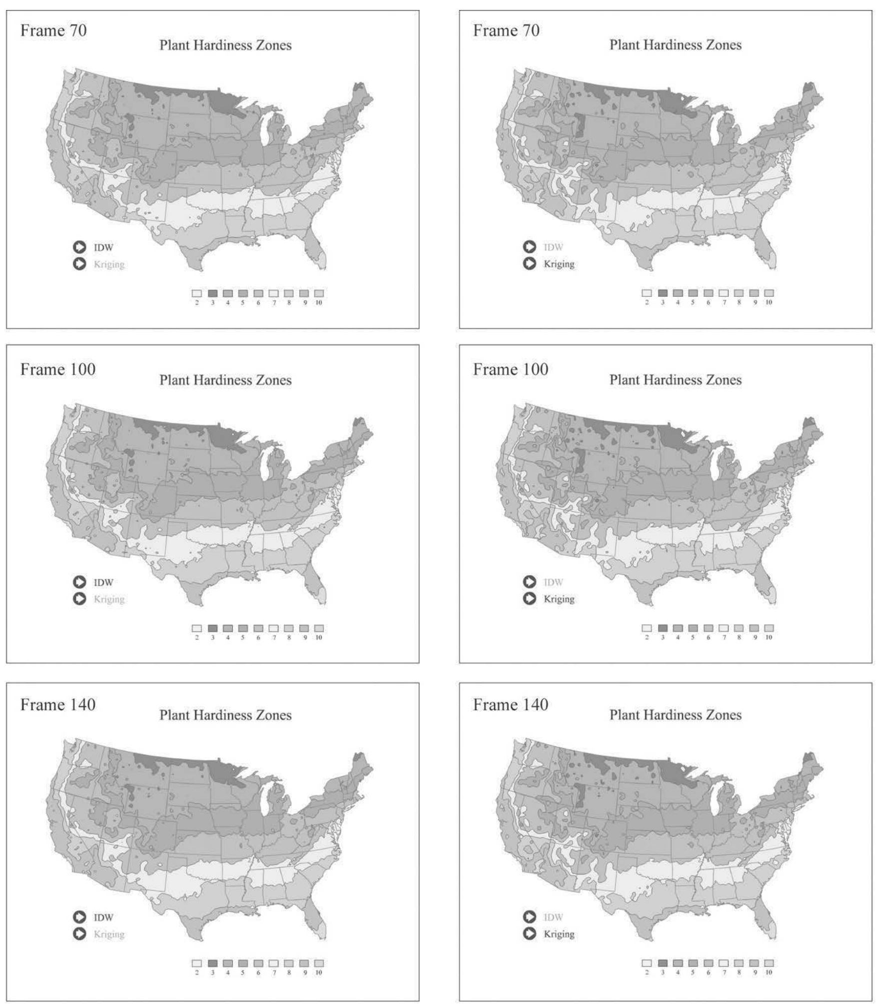

Figure 9. Selected frames from Animation 4. Frames on the left are IDW; frames on the right are kriging. (see page 75 for color version)

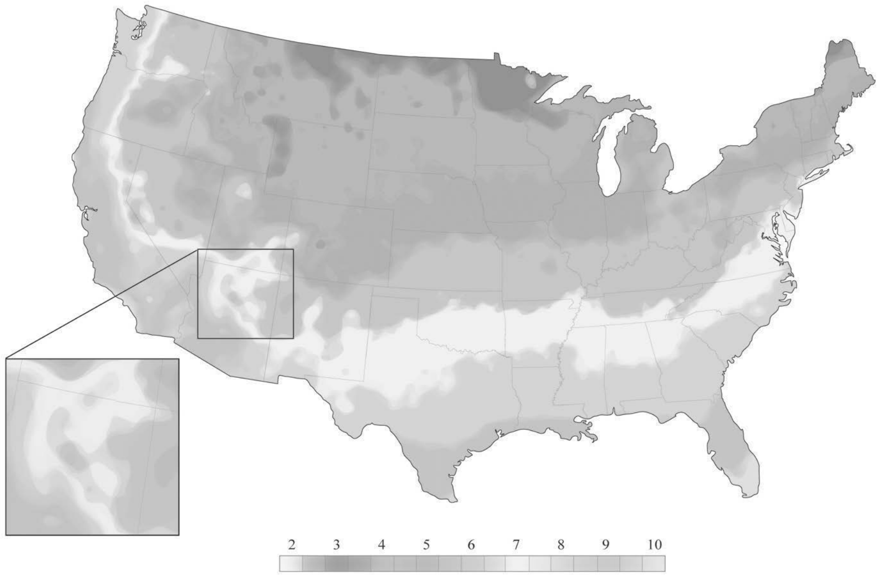

Figure 10. Composite map of 354 isometric representations of plant hardiness zones using kriging and IDW interpolation methods. (see page 75 for color version)

(e.g., green, yellow, orange) indicate places that are consistently assigned the same hardiness zone. In contrast, "mixed" hues (e.g., greenish-orange, yellow-orange) indicate places that are repeatedly assigned different hardiness zones. Rather than showing the results of just one interpolation method, our intention is to allow users to assess portions of the map where both kriging and IDW defined hardiness zones similarly, and places where they defined hardiness zones differently.

Conclusion

Cartographers have long recognized that all maps have a degree of uncertainty. We know that the conceptual and methodological decisions made during the mapping process can greatly affect the visual outcome of a particular map representation. While the entire process of map creation is an uncertain endeavor, the method-produced uncertainty associated with isometric mapping is exacerbated by the fact that the majority of data values shown on a map are predictions that cannot be verified. Even though cartographers know that isometric maps are highly uncertain and therefore, prone to misunderstandings, the exact nature and magnitude of this uncertainty for a particular map may be often unexplored, and is rarely conveyed to map users.

In using plant hardiness zones as a case study, we have attempted to show that when different methodological decisions are made in the interpolation process, very different maps can result. For plant hardiness zone maps, these visual and informational differences are not easily explained, and are not as predictable as that suggested by interpolation accuracy statistics. Despite these properties, isometric mapping continues to be a preferred method for many social and physical scientists, particularly in the fields of climatology and meteorology, where isometric maps are often used for analytic purposes, or to assist in policy decision-making. Use of the exploration and visualization techniques examined herein might direct map users to a better understanding of uncertainty about isometric map interpolation through visual, as opposed to numerical, means. We believe

". . . our intention is to allow users to assess portions of the map where both kriging and IDW defined hardiness zones similarly, and places where they defined hardiness zones differently."

that not only could these techniques assist map users in understanding uncertainty, they may also allow map users to feel more certain, when certainty it is warranted.

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Visual Representations of the Spatial Relationship Between Bermuda High Strengths and Hurricane Tracks

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The 2004 and 2005 hurricane seasons dramatically demonstrated the magnitude of the societal significance of hurricanes, negatively impacting on all scales from the personal to the national. Although definitive identification of the forcing mechanisms controlling hurricane tracks and landfall patterns remains elusive, increasing evidence supports the hypothesis that the increase in hurricane activity along the Gulf Coast is due to a southwestward shift in the position of the Bermuda High. This research uses multiple visualization techniques to explore the spatial correlation between Bermuda High strengths - as interpreted from the North Atlantic Oscillation (NAO) index - and hurricane tracks. Using hurricane vector data from the National Oceanic and Atmospheric Administration (NOAA) Hurricane Data set (HURRDAT) and NAO index data since 1947, the hypothesized spatial relationships were investigated. Due to the vast number of storm track segments (more than 17,000), displaying all segments in the same map failed to reveal any coherent spatial pattern. For this reason, storm track segments were converted into a point coverage, each point representing the mid-point of an original storm segment. Other visualization methods were applied to this new point coverage, including choropleth mapping and continuous 2-D and enhanced 3-D surface displays. The latter two methods were novel approaches for the visualization of large numbers of hurricane tracks and can be applied to any large data sets consisting of linear features. Results visually support a spatial relationship between hurricane tracks and Bermuda High strengths.

Keywords: Geographic visualization, kernel density estimation, Bermuda High Hypothesis, hurricane tracks

INTRODUCTION

Hurricanes play a significant role in the lives of the people living in high-risk areas, negatively impacting on all scales from the personal to the national. The ever-increasing concentration of people and properties in coastal areas has raised a serious question regarding hurricanes: Are there changes in the periodicity or return periods of hurricanes, and, if so, what is causing these changes? Paleotempestology, the study of prehistoric hurricane activity via the interpretation of proxy records (i.e., coastal lake sediments), allows us to look to the past to interpret long-term changes in hurricane landfall frequencies that far exceed the scope of modern instrumental data. By looking to the proxy record, paleotempestology allows for the interpretation of changes in hurricane landfall patterns spanning millennia.

"Paleotempestology is the study of prehistoric hurricane activity via the interpretation of proxy records."

Previous paleotempestological studies done on sediment cores taken from coastal lakes and marshes along the U.S. Gulf and Atlantic coasts show an anti-phase relationship in hurricane landfall frequencies between

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the two coasts. U.S. Gulf Coast studies (Liu, 2004; Liu and Fearn, 1993; 2000a; 200b) have shown that there was a period of increased hurricane activity during approximately 1000-3400 yr BP and decreased activity from 6000-3400 yr BP, as evidenced by a dramatic increase in the frequency of hurricane-deposited sand layers found in the lake and marsh sediments (Figure 1). Studies completed along the Atlantic Coast (Scott *et al.*, 2003; Collins *et al.*, 1999; Donnelly *et al.*, 2001a; Donnelly *et al.*, 2001b; Donnelly *et al.*, 2004; Lu and Liu 2005) indicate the opposite, a period of increased hurricane activity during the last 1000 yr BP and a period of relative inactivity during 1000-3400 yr BP.

The hypothesis that seeks to explain this anti-phase relationship in hurricane landfall frequencies is termed the Bermuda High Hypothesis. Liu and Fearn (2000a) hypothesize that during the Gulf Coast's hyperactive period of the late Holocene (3400-1000 yr BP) the Bermuda High

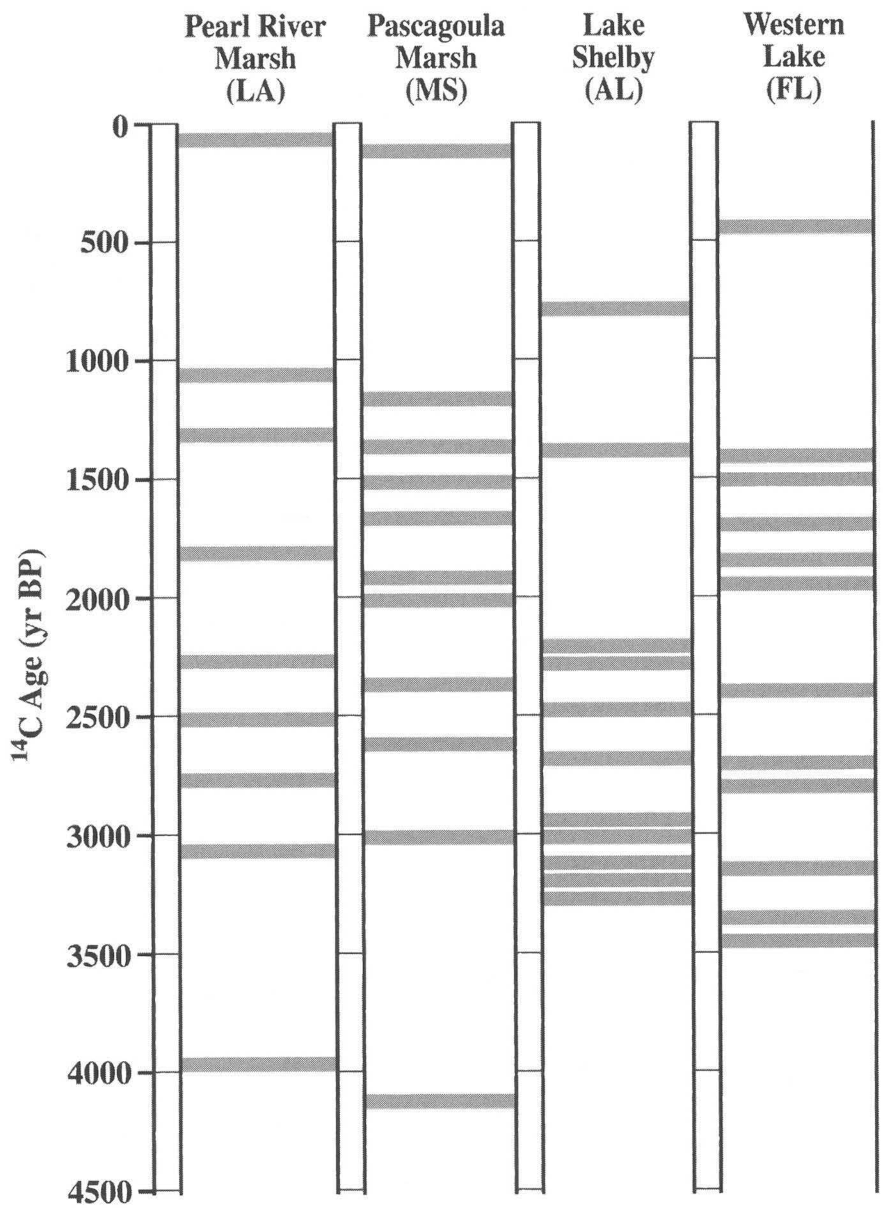

Figure 1. Chronology of catastrophic hurricane strikes along the U.S. Gulf Coast during the last 4,500 years (courtesy of Liu, 2004).

(also known as the Azores High or Atlantic Subtropical Anticyclone) was located southwest of its present position due to neo-glacial cooling and a southward shift in the jet stream. This southwesterly shift in the position of the Bermuda High would redirect the paths of hurricanes, leading to an increase in hurricane landfalls along the Gulf of Mexico Coast. Conversely, when the Bermuda High is in a more northeasterly position, closer to Bermuda, the Atlantic Coast experiences more hurricane strikes (Figure 2). The Bermuda High is thought to have a substantial influence on the direction and path of hurricanes (Elsner *et al.*, 2000; Elsner and Kara, 1999), but to date this relationship has not been tested visually or quantitatively.

The purpose of this research is to investigate the effect the Bermuda High has on hurricane tracks, testing the Bermuda High Hypothesis of Liu and Fearn (2000a). If the Bermuda High is indeed a factor in controlling the millennia-scale spatial shifts in hurricane landfall, a spatial relationship should be found between today's Bermuda High strengths and today's hurricane directions and tracks. Using different visualization techniques, this research seeks to explore, whether a spatial relationship exists between the modern-day Bermuda High strengths and the direction

"This research visually tests the Bermuda High Hypothesis."

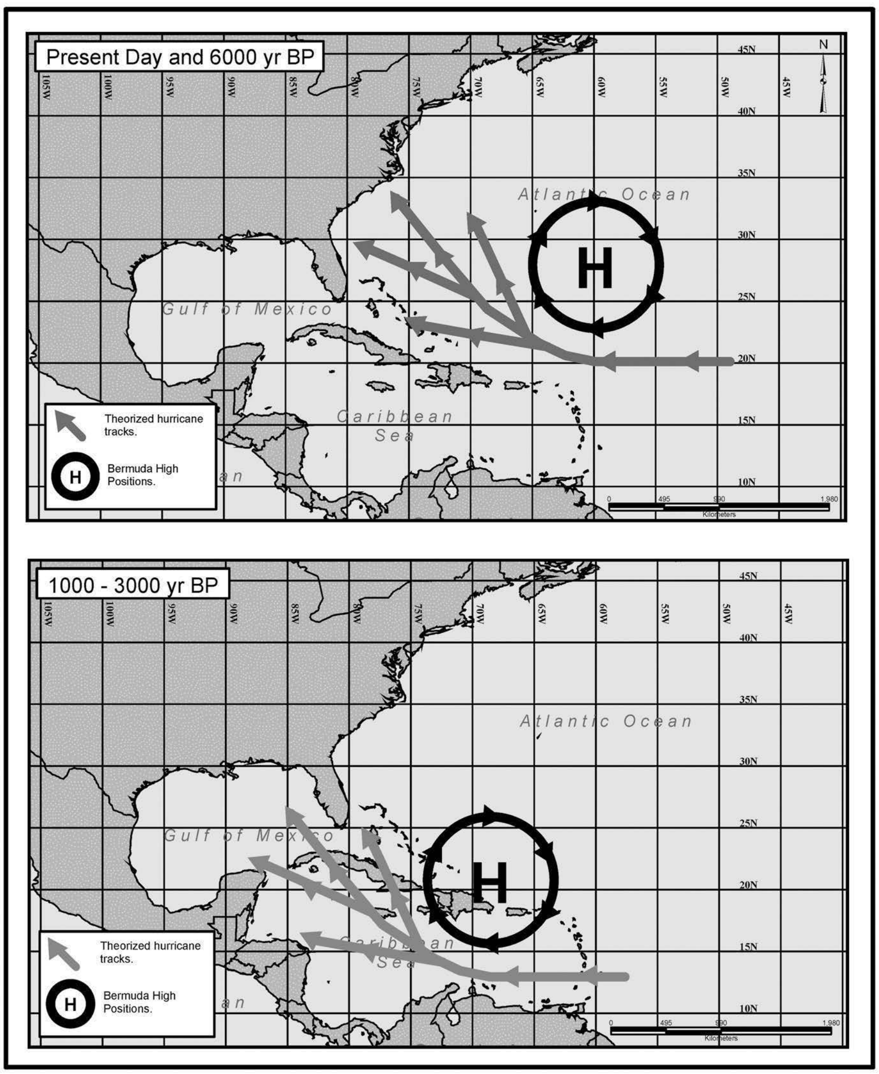

Figure 2. Relationship between the Bermuda High and hurricane tracks as expressed in the Bermuda High Hypothesis. (see page 76 for color version)

and path of modern-day hurricanes (Knowles, 2006). ArcView® GIS (ESRI, 1999), CrimeStat III (Levine, 2004), and Surfer (Golden Software, 2003) were used to visualize such possible relationships.

Background

Hurricane tracks are discrete linear features that have a starting and an end point. The logical map type to visualize such tracks is the so-called flow map, which shows linear movements between places. Hurricane tracks can be symbolized with flow lines of either uniform (no distinction is made between different hurricane strengths) or increasing line thickness to indicate differences in hurricane strengths (from tropical storms to category 5 hurricanes). Flow maps became especially popular in economic geography for mapping patterns of distribution of economic commodities, people (passengers), and any number of measures of traffic densities (Dent, 1999). Only recently has software for automated flow mapping become available. Examples include CrimeStat III (Levine, 2004), Tobler's Flow Mapper (Tobler, 1987), ArcGIS® (ESRI, 2005), and generatelines.dll, a tool that generates lines between locations. CrimeStat III (Levine, 2004) and Tobler's Flow Mapper (Tobler, 1987) can be downloaded from the following websites: http://www.icpsr.umich.edu/NACJD/crimestat.html/ and http://www.csiss.org/clearinghouse/FlowMapper/. The generatelines.dll tool is included in Groff and McEwen (2006), who also provide a detailed comparison of the three software packages. Unfortunately, flow maps are very poor at visualizing large amounts of flow lines that are spatially clustered, overlap, and criss-cross each other. Such a dense display of flow lines often masks any potential spatial patterns in the data.

"Flow maps are very poor at visualizing large amounts of flow lines that are spatially clustered, overlap, and criss-cross each other."

An alternative method to visualize hurricane tracks is first to split them into equally short segments and then replace each segment with a point placed at the center of each segment. Points can then be summarized for each cell of a regular grid placed on top of the study area. Such point densities can then be easily visualized with a choropleth map, which is defined by the International Cartographic Association as "a method of cartographic representation which employs distinctive color or shading applied to areas other than those bounded by isolines. These are usually statistical or administrative areas" (Meynen, 1973). In general, the choropleth map is easily understood by map readers and is therefore a popular visualization method. However, very "different-looking" choropleth maps can be derived from the same data depending on the classification method, areal symbolization, and size of administrative areas used. Any introductory cartographic textbook will provide a detailed discussion of the pitfalls of choropleth mapping (Dent, 1999; Slocum, *et al*., 2005; Campbell, 2001; Muehrcke, *et al*., 2001; Robinson, *et al*., 1995). In addition, the choropleth map assumes a uniform distribution within the same statistical area and can show rather abrupt density changes at the borders between an area and its neighbors. This latter drawback can be avoided when the center points of all hurricane segments are visualized using the kernel density interpolation method. This method creates smooth transitions between different density values.

The kernel density interpolation method has become a popular visualization method where the volume of incidents is relatively large and spatially clustered (Brunsdon, *et al*., forthcoming). It has, for example, been applied to investigate spatial and temporal changes in the retailing sector (Leitner and Staufer-Steinnocher, 2002); the dynamics of fire incidents (Corcoran *et al*., 2007); infant health analysis (Curtis and Leitner, 2006); crime hot spots (Eck *et al*., 2005); and concentrations of Foot and

Mouth Disease in South America (Curtis *et al.*, 2005). A detailed discussion of how the method works is provided below. In general, kernel density interpolation results can be visualized in the form of density maps (similar to choropleth maps but with smooth transitions between neighboring grid cells), isometric maps, or actual 3-D surfaces visualized with the popular fishnet (wire frame) structure. The isometric map is generated from data that occur at points and is one distinct form of the isarithmic map. Isarithmic mapping involves mapping a real or conceptual three-dimensional geographical volume with quantitative line symbols (Dent, 1999). Finally, an actual 3-D surface can be enhanced by draping additional information, such as the topography or shaded relief, over the original wire frame structure.

Data and Study Region

Hurricane data were downloaded from the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center website (http://hurricane.csc.noaa.gov/hurricanes/index.html). The data set consisted of every storm (ranging from extra-tropical depression to category 5 hurricanes) that occurred during the last 150 years. Each storm consisted of a multi-vectored track, divided into 6hr segments (over 35,000 records). The attribute data associated with each 6hr segment included, among others: the storm's name, wind speed, category, and pressure; the day, month, and year of the storm segment's occurrence; and the segment's location, expressed as x- and y-coordinates. For this project, a subset that included only hurricanes after 1947 (over 17,000 records) was also collected, since 1947 is considered to be the onset of reliable measured data. The 17,000+ records represented a total of 577 hurricanes.

In addition to hurricane tracks, data measuring the strength of the Bermuda High needed to be collected. While no direct measure of the Bermuda High exists, its strength can be interpreted from the North Atlantic Oscillation (NAO) index. The NAO is a coherent north-to-south seesaw pattern in sea-level pressures between Iceland and the Azores, and when pressures are low over Iceland (Icelandic Low), they tend to be high over the Azores (Azores High) and vice versa. Simply put, when the Icelandic Low is strong (low pressures), the Bermuda High is strong (high pressures), resulting in a positive NAO index. NAO index data were taken from Portis *et al.* (2001), who calculated such data as the difference in the normalized sea-level pressure anomalies at the locations of maximum negative correlation between the sub-tropical and sub-polar North Atlantic Sea Level Pressure (SLP). This means that the stronger (more positive) the NAO index, the stronger the Bermuda High; and the weaker (more negative) the index, the weaker the Bermuda High. The Portis *et al.* (2001) NAO index values range from -3.51 to +3.51 and were manually added to the database of the 17,000+ hurricane vectors.

Visualization of Hurricane Tracks

Geographic visualization of all 17,000+ storm vectors as line segments in the same map resulted in a very dense display, which hid any potential spatial patterns in the data (Figure 3). For this reason, a subset of the NAO index data was created that separated a "weak" Bermuda High category, with NAO index values smaller than -2.51, from a "strong" Bermuda High category, with NAO index values larger than +2.51. This had the effect of removing any moderating data and leaving only storm tracks that were associated with very strong or very weak Bermuda High strengths. This

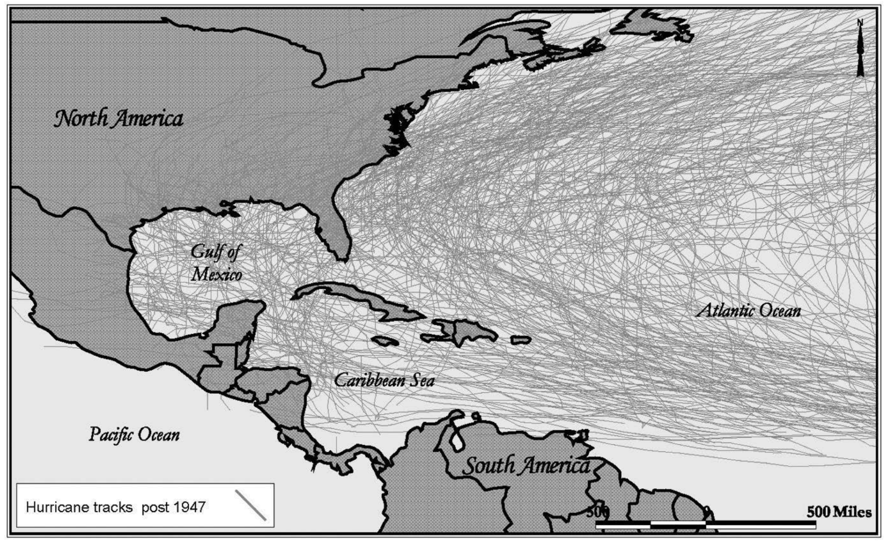

Figure 3. Visualization of all 577 hurricanes that have reached the Atlantic Ocean and the Gulf of Mexico since 1947. (see page 77 for color version)

subset resulted in 1,201 segments (47 hurricanes) associated with a "weak" and 825 segments (41 hurricanes) associated with a "strong" Bermuda High, respectively, for a total of 2,026 segments (88 hurricanes).

Geographic visualization of the subset of storm vectors associated with only the "weak" and "strong" Bermuda High categories resulted once again in a very dense map display that hid any spatial patterns. For this reason, each hurricane vector from this subset was converted into a point that was placed at the center of each 6hr storm vector. This resulting point coverage was used in all subsequent visualization efforts.

Choropleth Map

Visualizing the point coverage alone did not show any improvement over the previous two vector displays in terms of revealing any specific spatial patterns. However, overlaying a regular grid on top of the point coverage, counting the number of points falling into each grid cell, classifying the resulting "points-per-grid-cell" densities, and visualizing the densities with a sequential color scheme (Brewer, 1994), resulted in a much more useful visual display. This approach was carried out at three different grid cell sizes: 1° latitude/longitude, 2.5° latitude/longitude, and 5° latitude/longitude (Figure 4). While spatial patterns started to emerge using this choropleth method approach, maps still lacked smooth transitions between grid cells at all three resolutions. To further improve the smoothness of the visualization, the kernel density interpolation method was applied to the original point coverage.

Kernel Density Interpolation

The kernel density estimation is an interpolation technique that generalizes individual point locations or events, s_i, to an entire area and provides density estimates, $\lambda(s)$, at any location within the study region $\Re$ (Bailey and Gatrell, 1995; Burt and Barber, 1996; Fischer *et al.*, 2001). Density estimates are derived by placing a symmetrical surface, called the kernel function, $\kappa(.)$, over each event and summing the value of all surfaces onto a regular reference grid superimposed over the study region (Figure 5).

Typically, a symmetrical kernel function falls off with distance from each event at a rate that is dependent on the shape of the kernel function and the chosen bandwidth, *b*. A number of different kernel functions have been used, including normal, triangular, quartic, negative exponential, and uniform. The bandwidth determines the amount of smoothing and, for the limited distance functions (triangular, quartic, negative exponential, and uniform), the size of the kernel's search area. In the case of the normal kernel function, the bandwidth is the length of the standard deviation of the normal distribution. The normal kernel function produces a density estimate over the entire region (i.e., it is an unlimited distance function), whereas the other four functions produce estimates only for the circumscribed bandwidth radius. Kernel density calculations can be carried out for events that are weighted or unweighted.

"Selecting an appropriate bandwidth is a critical step in kernel estimation . . ."

Selecting an appropriate bandwidth is a critical step in kernel estimation; bandwidth affects the results to a much greater extent than cell size or type of kernel function. A larger bandwidth expands the kernel at the cell center and results in a smoothed and generalized map with low-

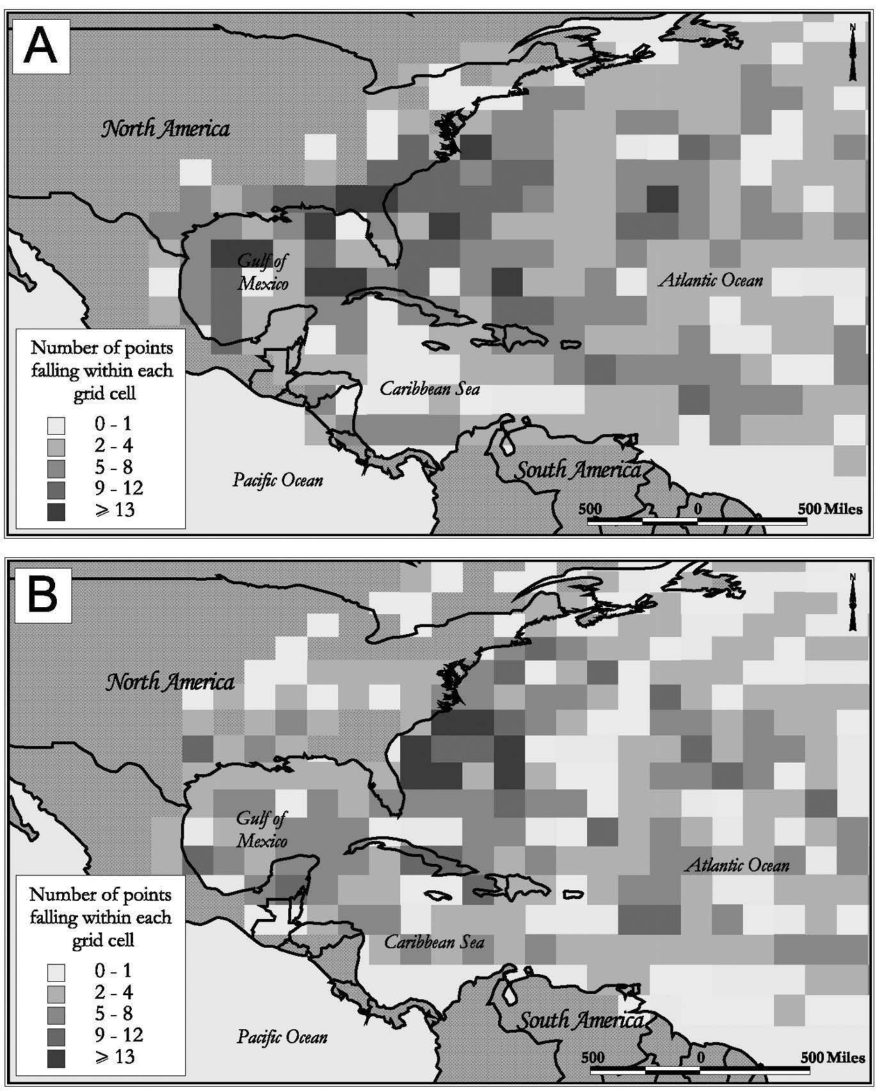

Figure 4. Choropleth mapping of hurricane density within a 2.5^{o} latitude/longitude grid cell size based on a "weak" Bermuda High (4A) and a "strong" Bermuda High (4B). (see page 77 for color version)

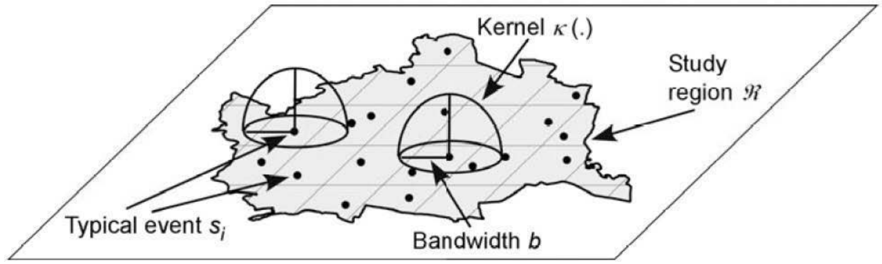

Figure 5. Kernel density estimation of a point pattern using the quartic kernel function (courtesy of Fischer et al.*, 2001).*

density values. In contrast, a small bandwidth results in less smoothing, producing a map that depicts local variations in point densities. A very small bandwidth almost reproduces the original point pattern and is spiky in appearance.

2-D Kernel Density Representation

Using the mid-point for each 6hr section of the storm tracks, a kernel density interpolation was calculated using CrimeStat III (Levine, 2004). Density calculations were based on a normal kernel function with a fixed bandwidth of 195 miles. This bandwidth selection is fairly conservative, considering that hurricane diameters range from 125 to 800 miles (Elsner and Kara, 1999). The normal kernel function was chosen because it is the most commonly used (Kelsall and Diggle, 1995).

"These results support a visual spatial correlation between modern-day Bermuda High strengths and modern-day hurricane tracks."

The results from the kernel density interpolations show the highest and lowest density of storm tracks in the darkest and lightest red, respectively. In contrast to the previously-discussed vector methods, spatial patterns now emerge more clearly. Hurricanes occurring during periods concurrent with a weak Bermuda High (highly negative NAO index) show little or no track re-curvature, with nearly all storm tracks showing east-west movement (Figure 6A). However, during periods concurrent with a strong Bermuda High (highly positive NAO index), hurricane tracks show large amounts of re-curvature along the western edge of the well-defined high pressure system (Figure 6B). These results support a visual spatial correlation between modern-day Bermuda High strengths and modern-day hurricane tracks.

3-D Kernel Density Representation

The final representation used the density values from the kernel interpolation method to create an enhanced 3-D display. This step was accomplished with the Surfer program (Golden Software, 2003). First, kernel density estimations were visualized in the form of a 3-D wire frame structure. This 3-D continuous surface was subsequently draped with (1) a simplified topographic map, showing only the outline of country boundaries and the land and water areas, (2) a shaded relief, and (3) an isometric map with hypsometric tints, but no contours (Figure 7).

"The enhanced 3-D surface clearly distinguishes between regions of high activity concurrent with strong and weak Bermuda High strengths."

The final, enhanced 3-D surface (Figure 8) is an improved visual representation compared to the 2-D display and clearly distinguishes between regions of high activity concurrent with strong and weak Bermuda High strengths. For periods with weak Bermuda Highs a general east-west trend of hurricane tracks is visible, indicative of a weak system exhibiting little or no control over the steering of the hurricanes. During periods

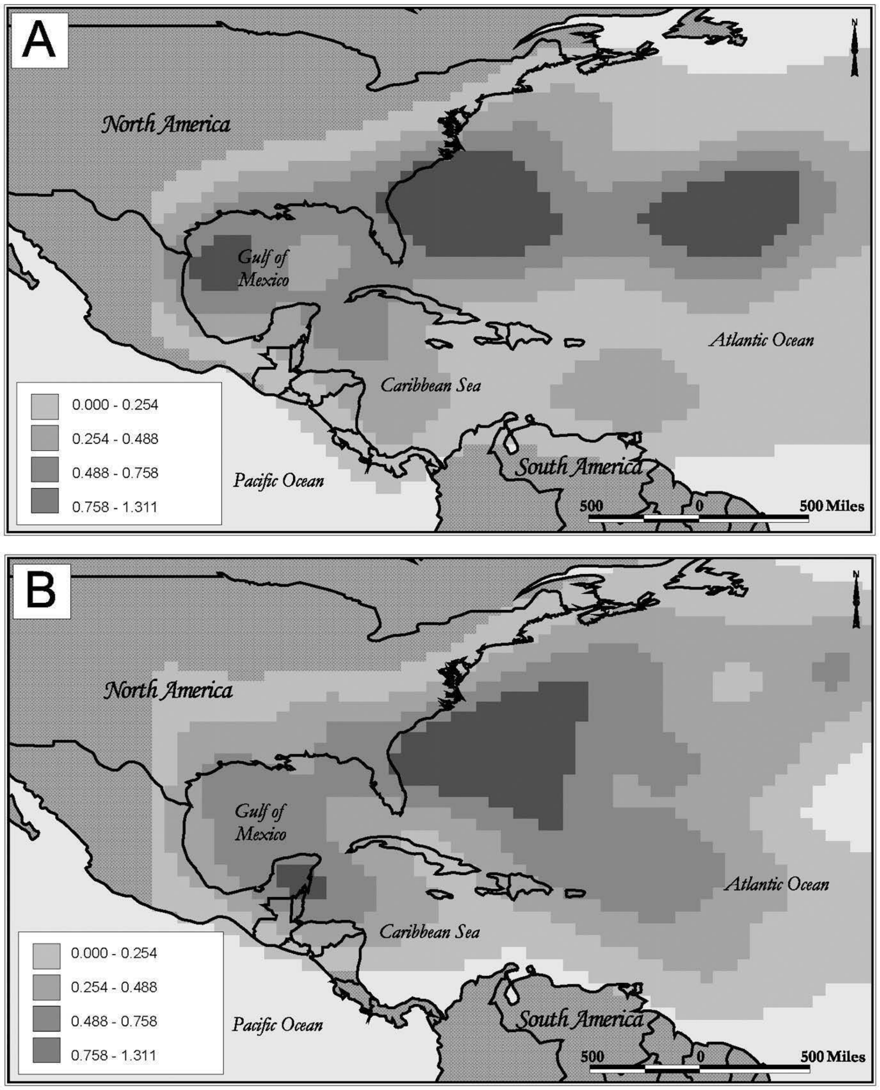

Figure 6. 2-D continuous surface display of hurricane tracks derived from kernel density estimations coinciding with a "weak" Bermuda High (6A) and a "strong" Bermuda High (6B). (see page 78 for color version)

when the Bermuda High is strong, hurricane tracks clearly exhibit a distinct pattern of re-curvature (Figure 8).

The 3-D enhanced surface representation is also compelling in that it illustrates changing risks associated with varying Bermuda High strengths. For example, according to the last 50+ years of data, when the Bermuda High is weak, the Caribbean Antilles (depicted with red circles in Figure 8) have a much lower occurrence of hurricane strikes. Alternatively, when the Bermuda High is strong, the same region's risk of hurricane strike increases dramatically.

Conclusions

The purpose of this research was to discover which visualization methods are best suited to detecting the spatial patterns of a large number of hurricane tracks collected for the Atlantic Ocean and the Gulf of Mexico since 1947. Specifically, the research visually tested the Bermuda High Hypothesis. The results indicate that, for periods concurrent with a strong Ber-

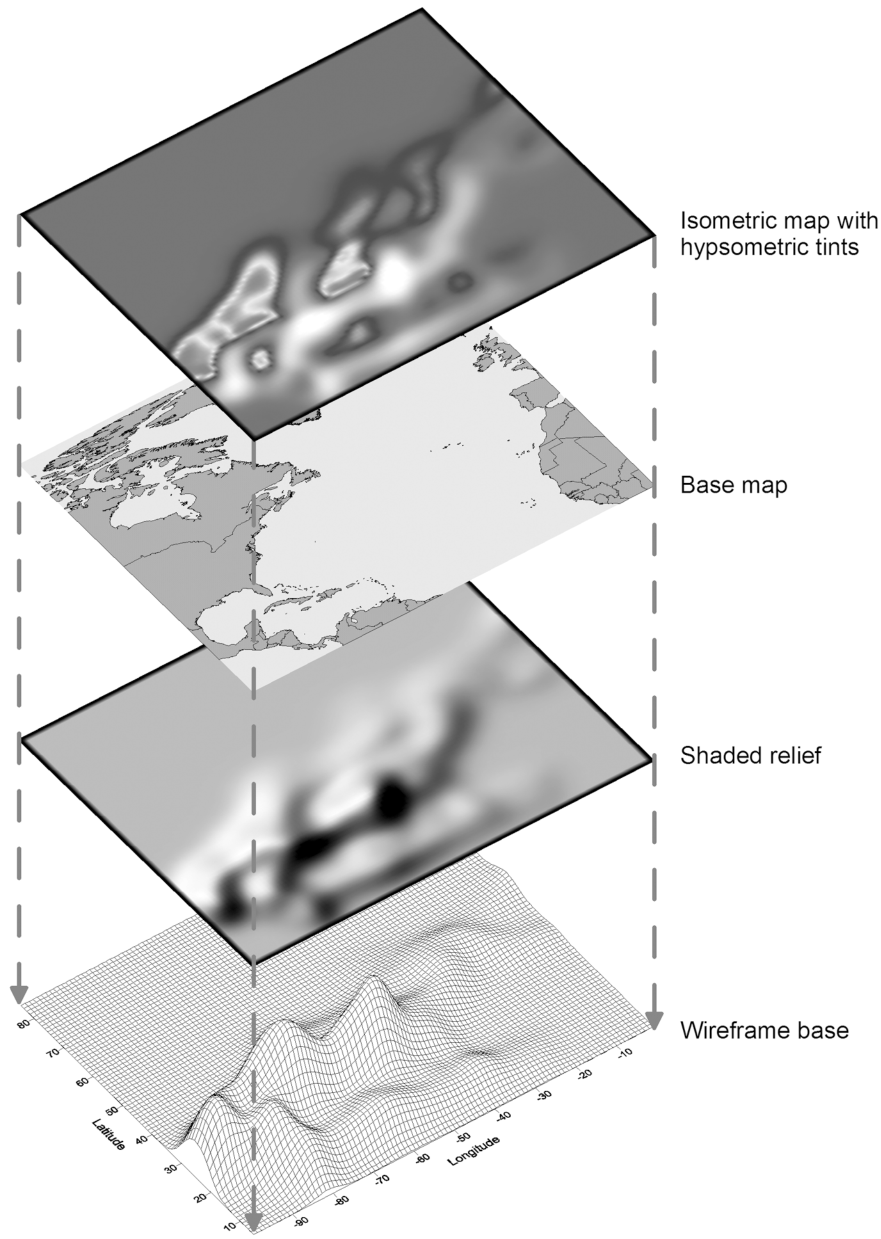

Figure 7. Schematic view of the components of the enhanced 3-D continuous surface display. (see page 79 for color version)

muda High, hurricane tracks show large amounts of re-curvature along the western edge of the well-defined (Bermuda High) pressure system, which is indicative of the Bermuda High as a controlling agent of hurricane tracks and is consistent with the stipulations put forth in the Bermuda High Hypothesis of Liu and Fearn (2000a). Hurricane tracks during periods concurrent with a weak Bermuda High are also in agreement with the Bermuda High Hypothesis, with hurricane tracks showing little or no track re-curvature but rather dominant east-west movement.

Among the different visualization methods tested, the 2-D and especially the enhanced 3-D representation, which are both based on kernel density interpolations, proved to be most useful. The spatial patterns exhibited by both visualization methods seem to be in agreement with the Bermuda High Hypothesis. To the best knowledge of the authors, this is

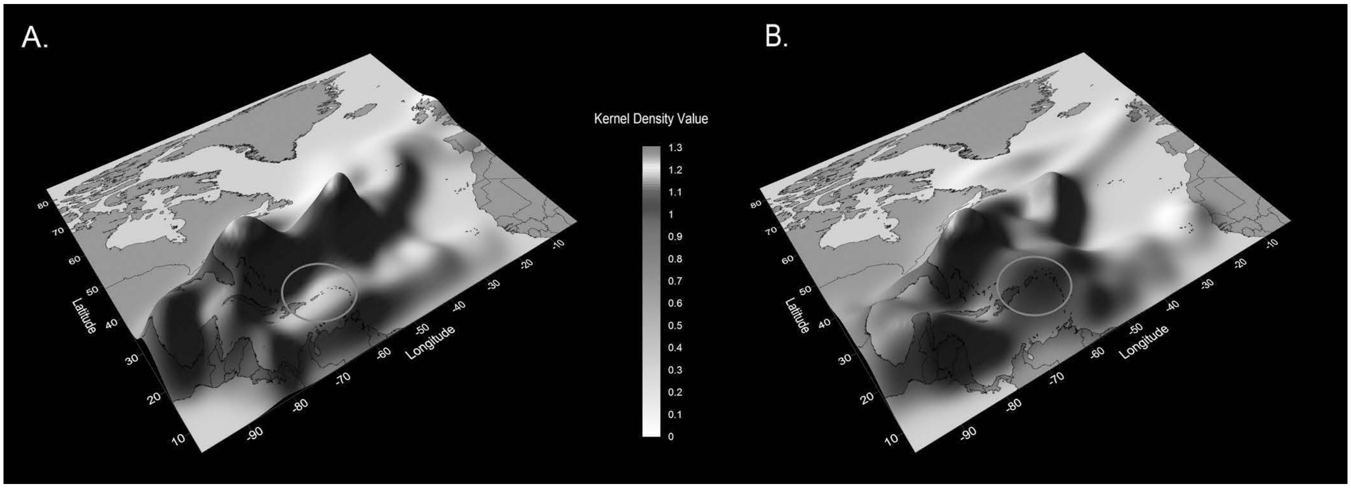

Figure 8. Enhanced 3-D continuous surface display of hurricane tracks derived from kernel density estimations coinciding with a "weak" Bermuda High (8A) and a "strong" Bermuda High (8B). Note: Red circles encompass the Caribbean Antilles and highlight changing risk associated with Bermuda High strength. *(see page 80 for color version)*

the first time that hurricane tracks have been represented in terms of their association with the strength of the Bermuda High using the kernel density estimation method. In general, the approach presented in this research should be useful for detecting spatial patterns in any large data sets that consist of linear features (e.g., migration patterns of birds or fish, urban traffic flows, patterns of drug trafficking or illegal immigration, and many others).

"This is the first time that hurricane tracks have been represented in terms of their association with the strength of the Bermuda High using the kernel density estimation method."

One drawback of the kernel density estimation is that its calculation is more complex and more time-intensive when compared to a traditional choropleth map that displays the density values for a regular grid. In addition, care must be taken when selecting the bandwidth used to calculate the kernel density values. Unfortunately, there is currently no agreement in the literature as to how wide a particular bandwidth should be (Environmental Systems Research Institute, 1999; Diggle, 1981; Williamson *et al.*, 1998).

An alternative approach to the fixed bandwidth is to use different bandwidths in different parts of the study area, an approach known as adaptive kernel estimation (Bailey and Gatrell, 1995). Adaptive kernel estimation is based on sampling theory, giving the choice of bandwidth a consistent level of precision over the entire study region. This is achieved by increasing the bandwidth until a fixed number of points (i.e., minimum sample size) are counted. Accordingly, in areas of high density, small bandwidths are used to show detailed local variation, whereas in areas of low density larger bandwidths smooth the point pattern (Bailey and Gatrell, 1995). Although adaptive kernel estimation solves the problem of determining a value for b, it still leaves open the question of how to set an appropriate minimum sample size. In general, the higher the minimum sample size, the larger the bandwidth and the more the density surface will be smoothed. Suggestions concerning the determination of the appropriate minimum sample size are lacking in the literature.

The main purpose of this research was to explore whether the Bermuda High Hypothesis could be tested using a series of geographic visualization methods. Results indicate that the 2-D and especially the enhanced 3-D display derived from kernel density interpolation seem to visually support the Bermuda High Hypothesis. This is in line with recent public safety (Eck *et al.*, 2005; Brunsdon *et al.*, 2007) and public health studies

(Curtis *et al*., 2005; Curtis and Leitner, 2006) that preferred to visualize large geospatial data sets of discrete (point or line) features that are spatially clustered with the kernel density interpolation method rather then with the choropleth or alternative methods. Although this is one indication that the kernel density interpolation method can "better" visualize large geospatial data sets, no human subject testing has ever been carried out to objectively validate this assumption. Such user studies become increasingly necessary as the kernel density interpolation method is implemented in spatial analysis software that becomes ubiquitously available (e.g., CrimeStat III).

"A more objective analysis is needed to verify the kernel density interpolation method's ability to visualize the relationship between Bermuda High strength and re-curvature of hurricane tracks."

With respect to this current study, a more objective analysis is needed to verify the kernel density interpolation method's ability to visualize the relationship between Bermuda High strength and re-curvature of hurricane tracks. Such an analysis would be the next logical step in this research and can be accomplished either through human subject testing or statistical analysis (e.g., correlation or spatial regression modeling). With regards to user studies, the two main assumptions that should be tested are (1) whether maps derived from kernel density interpolation are indeed "better" ("clearer," "more intuitive") at visualizing this specific relationship as compared to flow, dot, or choropleth maps; and (2) which parameter settings (i.e., bandwidth and kernel function) for the kernel density interpolation method would best visualize the relationship between Bermuda High strength and re-curvature of hurricane tracks. Human subject testing of this relationship would continue the recent resurgence of a long-standing tradition of empirical research in map design as a paradigm for eliciting and formalizing cartographic design knowledge (Leitner and Buttenfield, 2000; Aerts *et al*., 2003; Leitner and Curtis, 2004; Leitner and Curtis, 2006).

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Reviews

Field Methods in Remote Sensing
By Roger M. McCoy
New York: Guildford Press, 2005.
159 pages, Hardbound, ISBN: 1-59385-080-8

Reviewed by Jenny Hewson
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Field Methods in Remote Sensing is a very useful text for those who are new to the process of field data collection in remote sensing. Relatively few remote sensing-related field techniques books exist and this book provides a good first step overview. It discusses the many considerations involved in field work with reflected radiation, including the process of performing field work and the techniques and methodologies available.

The author's primary objective is to enable an individual with a remote sensing background to collect field data necessary for a suite of remote sensing projects. The text is aimed at three broad categories of readers including (1) students with a remote sensing background but limited field skills, (2) professionals with field skills, but needing help in applying those skills to remote sensing projects, and (3) teachers aiming to supplement a remote sensing course with a practical field component.

The author also highlights several additional objectives, including an introduction to basic methods for the measurement of vegetation, soil, water, and snow for different projects, and a useful bibliography for addressing specialized methods.

This text is targeted at a gap present in many remote sensing analyses: namely, the role and importance of field data collection. As the author explains, the details of field data collection process and procedure are often omitted from final product reports and methodology. *Field Methods in Remote Sensing* aims to address this gap by highlighting or surveying a suite of techniques for various scenarios and situations, enabling the reader to understand the different methods available for different field data collection needs. While this is not a *walk you through, step-by-step guide*, it provides an overview of many pertinent topics.

Chapters 1 through 5 focus on procedures and methodologies for use when collecting field data for all materials, while the remainder if the text deals with field techniques for use when considering specific materials.

The many practical considerations involved in performing fieldwork are discussed, and the critical need to outline the various steps of the project; including pre-fieldwork planning and identification of final project objectives, are presented. Potential problem areas and scenarios requiring consideration, such as sampling considerations (representative-ness and sufficiency, heterogeneity versus homogeneity), scaling up, locational error, the use of GPS, and the problems posed by insufficient knowledge regarding the phenomenon being sensed are examined, as is the use and limitations of aerial photos and thematic reference materials, especially with respect to training data. In addition, a discussion of field work type – quantitative vs. observational – with respect to the statement of objectives and goals is presented. Practical considerations, including the need for task lists and checklists of supplies and equipment, are not forgotten, either. A fieldwork project objective example, including initial project definition, and considerations for the collection of pre- and post-overflight data, is also included.

Selection of an appropriate sampling strategy is addressed through a discussion of considerations regarding the appropriateness of various strategies for different situations, highlighting both strengths and potential limitations that may be encountered. The various sampling strategies that are explained and diagramed include: simple random, stratified random, systematic, systematic unaligned, clustered, and purposive or judgmental sampling. A discussion of the number of training sites to select with respect to accuracy assessment and variability of surface under study is also presented.

The role of GPS is covered, including a brief history of GPS as well as the mechanics of GPS-ing: satellite constellation factors, single point vs. differential collection, and a discussion of error sources. Pre-field work GPS topics include map considerations and coordinate systems, the use of collection planning procedures, and calibration with known targets such as benchmarks. *In the field* topics covered include error source assessment, initialization of the unit, calibration with known targets, and other practical considerations.

The GPS chapter is, however, somewhat limited and this should be considered by the reader. For example, under the discussion of differential correction there is no mention of real-time vs. post-processing differential correction. In addition, neither the use of multi-point collection to increase locational accuracy, or the importance of using collection planning software as a way of increasing time-efficiency in the field get the attention they deserve. There is also only limited reference to the use of external antennas to lift a receiver up through the canopy as a way of addressing signal problems, while the process of initializing a unit in an open area before entering an obstructed area is not even mentioned. Finally, a discussion of the European Galileo constellation and achievable accuracy from this new reference system could be useful to the reader in the near future.

The chapter covering field spectrometry, by contrast, is particularly useful. A theoretical background on electromagnetic radiation principles is provided, and a step by step guide to the collection of field spectra is included. It is supplemented with a discussion of the assumptions involved in performing field spectrometry.

The various field techniques and considerations for specific phenomenon – primarily vegetation, soil, water, snow – are discussed in several chapters. The discussion of vegetation-related field techniques includes an overview of the spectral response of vegetation at different portions of the electromagnetic spectrum as well as the primary drivers of these responses. Attention is drawn to the need to focus on plant characteristics that are both measurable and that drive spectral responses, as well as to the most appropriate techniques and considerations regarding timing of vegetation cycles and the collection of field data. A discussion of various collection methods – line transect and pace methods, the use of quadrants, and collection for weight/volume analyses – is also presented.

The topic of soil field techniques includes an overview of the spectral response of soil at different portions of the electromagnetic spectrum and with different moisture and mineral contents. Also highlighted are the various soil properties that can be measured (color, texture, roughness, moisture content) as well as a summary of the techniques. The process of transforming soil field data into a map is addressed, as are considerations regarding the selection of soil sample sites.

One shortcoming is that while the text provides a useful and informative explanation of soil properties (texture, moisture, organic matter) particularly with respect to image interpretation, it does not consider the soil parameters such as soil color and texture from a sensor perspective or in a spatial context.

The use of field techniques for analyzing water is covered in the text, and includes an overview of the reflective properties of water in different states and with different turbidities, dissolved particles, algae, sediments etc. Techniques and methodologies discussed include those for analyzing water transparency, sediment composition, and water body depth.

When considering field techniques for measuring snow, consultation of additional source material would be advised as there is limited coverage in this book. While spectral properties and characteristics as well as the measurement methods available for assessing depth, areal extent, and water equivalence for snow are discussed, a comparison of the spectral characteristics of snow compared to cloud would be particularly helpful (perhaps with a graph highlighting these characteristics). Furthermore, a clarification regarding specific snow characteristics that can be differentiated by a sensor would also be useful. Is it, for example, possible to differentiate *old snow granular fine-grained* from *old snow granular coarse-grained* using a satellite-based sensor?

Finally, the unique situations encountered when mapping and monitoring urban environments are given a (somewhat limited) discussion. Specifically, the combination of multiple surface phenomena – vegetation, soil, water, bare, impervious – encountered in the urban context are addressed and the techniques available for use when producing land use maps, performing socioeconomic analyses, and performing urban hydrology assessments are highlighted. A great addition to this chapter would be a figure incorporating the spectral response of high density residential, low density residential, industrial/commercial land use. The sampling component of this chapter could, as well, be expanded with a discussion of the use of spatial enhancement techniques in mapping urban environments.

Conclusion

As mentioned above; *Field Methods in Remote Sensing* is a very useful text and it provides a good first step overview. However, the text might more appropriately have been titled: 'Field Method Considerations'. Several of the chapters leave the reader with the understanding that in order to collect worthy field data, additional sources will need to be consulted. Unfortunately, many of the sources (both citations and data sources) used throughout the book appear outdated. Online data servers are one rapidly evolving source of data that should be included in this text. For example, according to the author, ordering of TM data is accomplished by contacting EOSAT when, in fact, many online servers such as GLCF, TRFIC, EOS-WEBSTER, GLOVIS, and EarthExplorer now exist, all offering these data.

While this book may not go into great depth on the various topics covered, it does provide an extensive bibliography allowing the reader to further delve into the subject. A suite of useful field sheets are also included at the back of the book that can be used in various field collection scenarios.

Field Methods in Remote Sensing definitely addresses many of the issues and considerations that will be encountered during the process of field data collection. It is an easily readable book and explains the many concepts in a concise manner. This is not, however, a recipe book: it cannot be taken into the field and a plan directly executed from it. This is a good quick reference guide but not an all-encompassing text.

Remote Sensing for GIS Managers
Edited by Stan Aronoff
Redlands, California: ESRI Press, 2005.
xiv, 487 pp., 505 figures, 33 tables, footnotes, bibliographies, index
$69.95. Hardbound
ISBN 1-58948-081-3

Reviewed by Daniel G. Cole
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Upon seeing the title of this book and noting its editor, this reviewer, as a GIS manager with a background in remote sensing, knew that this tome would likely be worth reviewing. The field of GIS management has had Stan Aronoff at its helm since his publication of *Geographic Information Systems: A Management Perspective* in 1989. In his introductory chapter, he sets out the following plan for the book: "*Remote Sensing for GIS Managers* provides an introduction to remote sensing history, technology, and applications tailored to the needs of GIS managers and practitioners" and "introduces remote sensing with the goal of promoting its use in the production of useful geospatial information" (p. 7). This review will analyze how well he met those basic goals.

The book is divided into 13 chapters with three appendices, and while 15 authors contribute to the work, much of the book has Aronoff's signature. He is the single author of seven of the first nine chapters, plus two of the appendices; he co-authors two additional chapters and is one of the twelve contributors to the applications chapter. Except for the introductory and concluding chapters, all chapters have separate bibliographies and most have internet addresses for further information. As the editor, Aronoff has done a decent job of cross-referencing topics between his and others' chapters.

Chapters two and three deal with remote sensing history and basics, respectively. Aronoff expresses the valid concern that many "GIS users are often unaware that much of the data they use is generated using remote sensing technology or that much more information can be obtained from these sources" (p. 9). Fortunately, he addresses these concerns here and throughout the following chapters. In discussing the background of remote sensing, he doesn't bother to 'reinvent the wheel' regarding illustrative figures, but, instead, borrows extensively from authors of remote sensing college textbooks. He seems especially indebted to editions of Lillesand and Kieffer's classic work, *Remote Sensing and Image Interpretation* (2nd and 4th eds.).

The fourth and fifth chapters cover remote sensing image characteristics. Aronoff notes the confusion between ground sample distance (GSD) for digital imagery versus ground resolving distance (GRD) for aerial photography, and how GSD changes with resampling while GRD changes with enlargement or reduction of the photos. Within chapter four, he covers the four concepts of resolution: spatial, spectral, radiometric and temporal. A discussion of costs important to managers includes costs per unit area, for mosaicking, and for attaining visual thresholds necessary for mapping at various scales. He also relates the importance of positional accuracy to national map accuracy standards.

Chapter five, by Aronoff and Petrie, points out the importance of orthorectified imagery in a GIS environment. Here, they delve into the characteristic differences of digital versus film frame camera sensors while discussing different camera formats and stereo aerial photography. They outline the usefulness of aerial videography as well.

Line scanners are discussed in chapter six, with Aronoff outlining the differences between whisk-broom (across path) versus push-broom (along path) scanners and between multispectral versus hyperspectral scanners. This review is followed, in chapter seven, by an overview of current and historic, low to high resolution, satellite-based scanners with descriptions of each and of their data products. Aronoff finishes this chapter with a section, of import to managers, on the suitability for use of, and future of, high resolution imagery.

Chapters eight and nine cover the active sensors: radar, lidar and sonar. Aronoff and Petrie provide the principles of radar, including polarimetry, interferometry, penetration capabilities, elevation generation/accuracy assessments, and seafloor mapping from radar altimetry. They also point out the differences between imaging and non-imaging radar, and between real and synthetic aperture radar. The characteristics of lidar operations, sensors, imagery, and applications are described and followed with a discussion of sonar principles encompassing side-scan, acoustic lens, single beam, and multi-beam imaging systems as applied to bathymetric mapping.

At this point in the book, a problem with organization appears. Appendix A, by Petrie, which deals with rectification and geo-referencing of optical imagery, is found at the end of the book but might seem instead to fit better as a chapter here in the main text. This appendix, at 33 pages, is written like a chapter with figures, references and notes. Regardless, Petrie properly covers image geometries of frame cameras, line scanners, and radar imagery. He then discusses the equations involved in rectification and geo-referenced 2D and 3D imagery.

The tenth chapter deals with the visual interpretation of aerial imagery where Campbell limits the focus to scales of 1:40,000 or greater. He writes about imagery from archival sources and current custom acquisition, along with the advantages and disadvantages of each. He describes elements of image interpretation (shape, size, tone, texture, pattern, shadow, site, and association), as well as image interpretation tasks (classification, enumeration, measurement, and delineation) and strategies (field observation, direct recognition, inference, interpretive overlays, photomorphic regions, image interpretation keys, mosaics, and image maps). Critically, he discusses accuracy assessment of any interpretation with field observations, or ground-truthing, to discover errors of omission or commission. The author provides several pages of application examples and finishes with recommendations on finding image interpretation services.

Piwowar gives an extensive review of digital image analysis in chapter eleven. While several pages concerning image rectification at the beginning of his manuscript overlap Appendix A, the rest of his chapter provides much needed information on image enhancement, classification, analysis, and modeling. The first of these is divided into sections on brightness and contrast enhancement, edge enhancement, band and temporal selection for composite generation, and indices to enhance image quality. This last item is expanded upon in two subsections concerning: (1) the normalized difference vegetation index (NDVI) and the more recently developed enhanced vegetation index (EVI); and (2) indices of image characteristics such as image texture measurements and principle components analysis. Piwowar logically notes that "development of a rigorous and complete set of class definitions is critical to the success of classification analysis" (p. 307). He then follows this discussion with others about land-use versus land-cover mapping, different types of supervised and unsupervised digital classification schemes, and accuracy assessments. Other details on classification approaches, including hybrid-, contextual-, and fuzzy-classifications, along with spectral mixture analysis, artificial neural networks, and object oriented classifiers are also presented. The next two sections of this chapter deal with change analysis and modeling, with examples of descriptive modeling (Southwest Regional Gap Analysis Project) and predictive modeling (Gypsy moth damage potential in Minnesota). The author finishes up with his concerns regarding remote sensing imagery integrated in the GIS environment, file exchange formats, data volumes and class filtering. Concerning file exchange formats, an update (2004) on JPEG2000 should have been cited here (http://www.jpeg.org/apps/sensing.html).

Reading the above chapter points out a major omission in the book, i.e., no discussion, much less any mention, appears here or in the appendices in regard to different image processing programs such as ERDAS Imagine, PCI Geomatica, Intergraph ImageStation, TNTmips, ENVI/IDL, ER Mapper, or IDRISI. This book is not intended for students; rather, it is obviously directed to managers who would appreciate a set of tables comparing the features of the above software packages. No commercial promotion is necessary but any manager needs to know which product might best serve his or her project needs.

Chapter 12, dealing with remote sensing applications, is the longest chapter in the book, and rightly so. It is divided into eight sections and case studies, each with different authors and its own bibliography. Aronoff himself starts with the agriculture section covering regional crop condition monitoring and precision farming implementations of geospatial technology. Wulder et al. cover forestry applications including detailed forest inventories, forest health and natural disturbances, and landscape ecology, habitat and biodiversity. This section is followed by two case studies: (1) analysis of jack pine budworm defoliation (Hall); and grizzly bear habitat mapping and modeling (Franklin). Here, and elsewhere in this chapter, are included valuable summaries of end-products, time frames, and costs. Geologic applications are handled by Berger and Fortin, who describe the key geologic structures as detected on remotely sensed images, as well as direct detection of hydrocarbons. Their case study involves an integrated analysis of the Gabon sedimentary basin. Next, Gallo gives a quick overview of the appropriate satellites involved with atmospheric, oceanographic and land products. Madry discusses archaeological applications such as archaeological site discovery, and regional archaeological environmental analysis, with case studies on Burgundy, France and St Johns County, Florida. The next two sections, military applications (Aronoff and Swann) and intelligence analysis (Last), inevitably overlap while dealing with reconnaissance and military intelligence. The former section provides a table of applications and specific military uses of remotely sensed data while the latter gives a case study of military intelligence scenarios. The last application section (Hipple and Haithcoat) concerns urban infrastructure and business geographics and includes subsections on planimetric base mapping, detailed topography, land cover/land use, urban forest/greenspace, infrastructure condition assessment, development monitoring, emergency response and disaster management, and business development, planning and analysis.

The concluding chapter on remote sensing and the organization (Merchant) contains a wealth good advice packed into a few pages. In writing about the implementation phase, when he addresses assessing needs, he promotes the potential benefits of remote sensing while cautioning the reader to recognize the difference between experimental success versus operational applications. In addition, he recommends determining the organization's information requirements through the creation of pilot projects. Concerning human resources, the frequency of use of remotely sensed data using image processing programs demands in-house capabilities, along with a commitment by management to training so that staff will stay up-to-date with current technology. He suggests that most, if not all, GIS shops need at least one full-time staff remote sensing expert. This suggestion is made so that proper oversight is maintained regardless of whether or not remote sensing work is done in-house or contracted out as is the case with small shops, infrequent users, or when special skills are involved. This oversight would include quality assurance awareness of data analysis strategies involving various modes of image classification so that misapplication of an incorrect technique is avoided. Developing partnerships or working as part of a consortia are also forwarded as a means of building on each other's strengths, especially with an interdisciplinary focus, so that data, imagery, personnel and costs are shared. Needless to say, he concludes with "Remote sensing is a potentially powerful compliment to GIS technology." (p. 419).

With Appendix A already noted above, Appendix B provides the characteristics of 17 selected satellite sensors in tabular format. Appendix C lists remote sensing and related resources, including: 15 educational web sites, 17 tutorials, eight books, 17 periodicals, six associations, five remote sensing and earth science web glossaries, data resources from seven international government agencies and eight commercial satellite and radar sources, and eleven image galleries on the web.

As an edited work, some unevenness and overlap expectedly occurs, although Aronoff wisely cross-references statements and sections between chapters. While I have noted some problems with the book, my complaints are mostly quibbles, and I will wholeheartedly recommend this book, especially if future editions include tables comparing the capabilities of different image processing software packages.

Literature, Mapping, and the Politics of Space in Early Modern Britain

Ed. Andrew Gordon and Bernhard Klein. Cambridge: Cambridge UP, 2001. 276pp; 30 ills. Hardbound. ISBN# 0-521-80377-2. $85.00.

Reviewed by Brooks C. Pearson
University of Central Arkansas

This book is nicely bound and wrapped in a rather outdated dust jacket reminiscent of the 1970s. Both binding and jacket house a very peculiar assemblage of essays loosely unified by their treatment of one or more of the themes indicated by the book's title. None of the entries attempts to engage all titular themes, while several only seem to stab unsuccessfully in the general direction of one or other of them. The book's twelve contributing authors are primarily scholars of English literature; none are geographers. No chapter engages period historical cartography in a fashion recognizable to cartographic scholars, although a few make a cursory attempt to apply the conventions of literary criticism to a deconstructive analysis of atlas frontispieces or map cartouches. Most chapters make some effort to engage ideas that could be construed as "geographic," although – as with the book's "cartographic" inquiry– these efforts are nearly without reference to the relevant geographic literature. Overall, this book will likely be very unsatisfying to cartographic scholars, specifically, and to geographers, generally.

Articles in this book frequently flirt with ideas long established in the geographic or cartographic literature without any apparent awareness that such a body of knowledge exists. The first chapter is a good example of the scholarship typical of this work. Oliver Arnold's "Absorption and Representation: Mapping England in the Early Modern House of Commons" attempts to use Parliamentary records and other primary sources to outline the British lower house's conceptualization of itself as a mirror of the Realm in the late 16th century. Arnold seeks to establish that the physical layout and customary procedures of that political body were consciously analogous to the citizenry and social relations of the nation. All this is accomplished without reference to the wealth of literature on mental mapping, activity spaces, and similar geo-cartographic themes which could have greatly informed the discussion. A similar lack of awareness of the relevant literature also handicaps the book's two articles on the role of mental mapping in Edmund Spenser's *The Faerie Queen*. Bernhard Klein's "Imaginary Journeys: Spenser, Drayton, and the Poetics of National Space" and Joanne Woolway Grenfell's "Do Real Knights Need Maps? Charting Moral, Geographical, and Representational Uncertainty in Edmund Spenser's *The Faerie Queen*" both examine how characters must navigate Spenser's fairy world by developing cognitive maps and intuitive geographical understanding rather than through the use of tangible maps and geographical knowledge gained in the real world.

Oddly, considering the prominence mapping is given in the book's title, most chapter authors fail to appreciate that the cartographic document is anything more than a pretty picture to illustrate their discussions. Most of the maps reproduced in the book are either entirely irrelevant to the discussion (as in Nina Taunton's "Unlawful Presences: The Politics of Military Space and the Problem of Women in *Tamburlaine*"), or largely ignored by their respective articles. As with Lesley Cormack's "Britannia Rules the Waves?: Images of Empire in Elizabethan England" , most of the book's authors fail to fully engage the cartographic discourse itself, but are instead content to rely on cursory comparisons of frontispieces and marginal illustrations when examination and comparison of the mapped information would have led to far more substantial (and better substantiated) conclusions. The discourse on cartography is downright silly in some chapters, as in John Gillies's "The Scene of Cartography in *King Lear*," which is devoted to studying whether or not a fictional map existed on-stage at the Globe Theater even though this controversy is irrelevant to the audience's interpretation of the play's action.

There are three chapters in this book that are at least reasonably satisfying. Philip Schwyzer's "A Map of Greater Cambria" provides a succinct summary of the historical Welsh claim to the Severn River as the principality's natural eastern boundary. This discussion concentrates on Humphrey Llwyd's geopolitically fanciful 1573 map of Cambria (Wales) which appeared in Ortelius's *Theatrum Orbis Terrarum*. Llwyd's map and several literary pieces from the period (such as Michael Drayton's *Poly-Olbion*) were part of a nostalgic movement among some British intellectuals to enlarge Wales to its supposed former boundaries. Richard Helgerson's "The Folly of Maps and Modernity" presents an interesting discussion of the relationship between maps, painting, and nationalistic propaganda during the early modern period. According to Helgerson's discussion, maps and genre paintings were vehicles to inspire a sense of European superiority through demonstrations of the global grasp of colonialism and commercialism. Caterina Albano's "Visible Bodies: Cartography and Anatomy" offers an intriguing discussion of early modern conceptual linkages between the landscape and the human body as evident in John Speed's 1611 atlas and in several anatomical treatises of the day (although she overlooks a delightful visual pun in her Figure 13 (p. 99) which illustrates the human brain by showing a prostrate, decapitated human figure surrounded by likewise decapitated landscape features such as tree stumps and a ruined castle).

What I found most inexcusably lacking in this book– besides a productive point to many of its essays– was any treatment of the Enclosure movement. The process of progressive removal of lands from public use by their enclosure into the domains of wealthy landlords was one of the most important geographical phenomena of early modern Britain. By disrupting the subsistence potential of rural families throughout the British Isles, Enclosure provided the souls who began filling English cities during this period and thereby bolstered both the incipient Industrial Revolution's labor supply and the surplus peasantry which would ultimately be shipped to the colonies in America and elsewhere. This issue was not only political but also cartographic, as scientific mapmaking provided both the means to facilitate enclosure and the legal documents to codify it (see, for example, Allen (1993), Slater (1968), Turner (1980), and Yelling (1977)). It is inexplicable why this book overlooks an important geopolitical and cartographic phenomenon so intimately intertwined with its period and with its stated focus.

It has been very difficult to find positive, constructive things to say about book. Most articles seemed pointless, and nearly all represented a very low level of scholarship in their almost complete ignorance of relevant geographic and cartographic literature. This book is definitely not worth purchasing with personal resources, and only worth ordering for a university library if one's budget is limitless.

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Maps as Mediated Seeing: Fundamentals of Cartography
Written by Gerald Fremlin, with Arthur H. Robinson
Published in 2005 by Trafford Publishing, Victoria, BC, Canada
272 pages, 15 figures, 1 table
$26.96 (US) softcover
ISBN 141206682-4

Reviewed by Mary L. Johnson
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The authors of *Maps as Mediated Seeing* propose to answer the age-old question, "What is a map?" Yet, the one thing the reader can't help noticing when paging through this book is that there aren't any conventional geographic maps inside. There are a handful of diagrammatic images with varying levels of visual appeal, but no color insets, no fold-outs: no true geographic imagery of any kind, not even on the cover. This seems very strange at first, particularly considering the impressive cartographic backgrounds of the two authors.

Arthur H. Robinson was a Professor of Cartography at the University of Wisconsin, Madison for many years and is perhaps best known as the author of *Elements of Cartography*. He died in retirement in 2004 at the age of 90. Gerald Fremlin is Canadian, and served in the Royal Canadian Air Force in World War II. He worked on *The National Atlas of Canada* through the Geographical Branch, Ottawa, ultimately becoming its editor-in-chief. He did graduate work under Arthur H. Robinson in the early 1960s. This book began through that initial association and continued as a post-retirement project for Fremlin, with Robinson providing edits and comments.

The authors are quick to note that many books have been written on what a map is, but these have mostly reflected on the various uses of maps rather than on what constitutes a map itself. A good map is more than just a source of geographical reference. A good map, according to the authors, is a type of trompe-l'oeil art that seeks to trick the viewer's eye into seeing three dimensions where only the one-dimensional paper image actually exists. The objective of map design is to balance detail with legibility in such a way as to enhance that three-dimensional impression while still providing the related annotation and symbology needed to fully portray the area represented. The latter must be done in almost subliminal fashion in order to effectively succeed.

Mediated seeing is defined here as seeing by representation. Watching movies or television, viewing photos, or looking at a map are all versions of mediated seeing. We, as the viewers, are not actually experiencing the subjects as we would firsthand, yet we have been drawn in somehow on another plane and provided with a type of firsthand knowledge we could not otherwise have achieved. Those stereotypical "you are here" maps provided in many public parks and tourist destinations are perhaps a perfect example. The viewer becomes part of the surrounding environment and is quickly acclimated, able to "see" if a desired destination is east or west, left or right of where the viewer is standing.

A very important point about mediated seeing has to do with perspective. This is particularly true when we describe an image or representation of a geographic feature to others. If we are looking at a photo of a mountain, for example, we would describe the mountain as being *in* the picture. However, if we are looking at a map of the same mountain, we would describe the mountain as being *on* the map. This is because a photo makes us feel as if we are looking at something on the same plane. Our eyes are drawn from foreground to background, as if looking through a window at the world beyond. A map, on the other hand, tends to provide a more three-dimensional representation of an area, and even a virtual sense of altitude. The distance between the eye and the map actually makes it seem as if we are floating over the area portrayed. Hence, the mountain is *on* the map in the same way it is *on* the earth below.

Two types of maps are analyzed in this book: topographical maps and thematic maps. Topographical maps offer a truly visual, geographical perspective of an area: whether is it flat or mountainous, wooded or desert, coastal or inland. Thematic maps, on the other hand, show how an area is from more of a non-visual, scientific perspective: whether the climate is hot or cold, whether the population is dense or sparse, or whether regional income is agricultural or industrial in nature. Of the two types, topographical maps are covered first, and in greater detail.

Although all maps tend to be models of the earth to some extent, topographical maps are particularly helpful for defining the surface characteristics of the earth. This can be done through various means, including careful application of symbology and color. Map symbols can be associative, such as using an airplane to represent an airport, or more generic, such as using a small square to represent any kind of building. Annotation is also a very important part of symbology, as it further defines each individual site.

Using color on a map is another means of enhancing the viewer's overall comprehension of the area portrayed, since geographical detail will likely stand out more in color than it will in black and white. Consider the effectiveness of using blue to represent water features on a map rather than shades of black or gray.

This is true regardless of whether the viewer is looking at the map as a whole or trying to focus on a particular geographic feature.

Lines are also important features on topographical maps. A simple change in line color, line style or line thickness can denote various types of boundaries, geographical contours, or even latitude/longitude information. The effectiveness of contour lines for providing three-dimensional relief imaging is demonstrated in this book not with a geographic map, but with a contoured face derived by photogrammetry. The detail is striking.

Thematic maps are considered "process" maps in that they depict the processes of change. Several categories of thematic maps are briefly presented. Geophysical maps show the processes of change on the planet itself, and include geological and climatological maps. Historical maps show the processes of mankind's exploration or settlement of an area over time. Demographic maps deal with the process of population distribution and its effects on familiar quality-of-life concerns. Economic maps show the processes of change that impact a region's economy, such as income levels, natural resources, and output capacity of various industries. Correlating maps show the relationship process between two or more differing subjects, such as how the amount of annual rainfall relates to crop success in an area.

One important point that consistently comes up in the municipal mapping field I work in is the importance of a good base map foundation for all mapping projects. *Maps as Mediated Seeing* drives home this point by describing the important relationship between thematic data and the topographical base. In other words, without a good base map to anchor it, thematic data would be reduced to an abstract swirl of colors or an ambiguous set of figures. Conversely, without thematic data, even the best topographical base map would provide only limited information about what an area is really like, since it concentrates solely on terrain and landscape. Our sense of the world is not only visual or even tactile in nature, but built upon other sensory and intellectual information as well. Combining thematic data with a topographical base creates a true "All Senses Map" that allows the viewer to experience things that are not "seeable" in the conventional sense, such as temperature variations, annual rainfall, population densities, and land use. This, too, is a form of mediated seeing.

Thematic maps are further defined and explored later in the book, particularly the use of chloropleths to depict information through gradations of color. The use of pictures and other graphics to enhance a map is also briefly examined from both a positive and negative perspective.

An Afterword provides a brief look at the future of cartography, which is now largely defined by the use of GIS technology. GIS allows the digital cartographer to be more prolific than the traditional mapmaker could ever have imagined. Since GIS is not limited by paper, it can offer incredible opportunities, not the least of which is the ability to easily zoom through multiple map scales in order to examine an area at varying levels of detail. The same regional information that once required an entire atlas to display is now seamlessly available in digital format right at the cartographer's fingertips.

The first and last chapters of the book contain various short essays on mapping subjects that are interesting in and of themselves, but do not otherwise fit into the overall subject matter explored. The book also includes a glossary of terms, a detailed bibliography and a subject index.

I have always felt that mapmaking is as much an art as a science. This theory is corroborated for me whenever I compare two seemingly identical maps of the same location created by two distinct sources. The setting may be shared, but the resulting imagery is seldom alike. The differences between the two may be subtle or they may be extreme, but they are most often reflective of artistic expression. For this reason, I was not surprised that no definitive or encyclopedic answer was provided to the book's opening question, "What is a map?" The authors have instead shared with us their accumulated wisdom, allowing each of us to formulate a satisfactory answer on our own.

As its subtitle suggests, this book examines the fundamentals of cartography and expands upon them in painstaking detail, taking simple ideas that might otherwise be only an afterthought to most readers and transforming them into immensely important principles in the overall process of mapmaking. For example, the intricacies of the legend are carefully explored, and how its composition and application can ultimately enhance or overcomplicate a particular map. The book also has extensive footnotes, and in fact, there are more footnotes than text on some pages, which occasionally makes it difficult to follow.

I would not recommend this book for anyone without a serious interest in cartography and all its aspects. In the book's Acknowledgements section, it is noted that *Maps as Mediated Seeing* was originally published in the journal of the Canadian Association of Cartographers [sic, Canadian Cartographic Association] in 1999, and was considered by many "a hard read." Considerable work and editing was performed to make it "a little more user-friendly," but it is still a very intense read. This is not the sort of book that the reader could simply glance through at leisure or pick up in the middle with very much success. Each new chapter naturally follows and builds upon the previous chapter, bringing the reader systematically to the crux of the subject just as successive contour lines on a topographical map will ultimately bring the viewer to the apex of the summit. For those readers who are prepared for the climb, it is a journey well worth taking.

Seeing Through Maps: Many Ways to See the World
Written by Denis Wood, Ward L. Kaiser and Bob Abramms
Published in 2001, 2005, 2006 by ODT, Inc., Amherst, MA. 152 pages, 78 illustrations and *Appendix of Map Projections.* $24.95 (US) softcover
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Many Ways to See the World (Companion DVD)
By Dr. Bob Abramms
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ODT, the publisher of *Seeing Through Maps*, has a mission that includes "teaching people to see the world from a broader, more inclusive perspective." This book, and the team of authors responsible for it, attempts to do just that in regard to world maps and related imagery.

Denis Wood is a writer/artist and social scientist with a keen interest in maps. He is the author of *The Power of Maps*, as well as numerous articles on a variety of socially relevant subjects. Ward L. Kaiser is a publisher, pastor, teacher and community organizer. He introduced the Peters Projection to North America by publishing its first English language version in 1983.

Dr. Bob Abramms is an expert on management training and executive development programs. He has conducted seminars on "Managing Cultural Differences" for a wide variety of clients. His companion DVD, "Many Ways to See the World," is based on imagery from *Seeing Through Maps.* The DVD is offered separately at an additional cost and is discussed later in this review.

The book *Seeing Through Maps* begins by briefly examining the concept of truth in our daily lives. To a large extent, truth depends on a person's point of view. For example, two people having lunch together will not experience the meal exactly the same way, since they are looking at it, literally, from opposite sides of the same table. One person is looking in one direction, and one person in another, so, although they are together for the same meal, they are having different experiences because of their unique vantage points. Truth as it applies to mapping is similar in nature. Whether we consider a map "good" or "truthful" generally depends on our point of view.

All maps have a purpose. The overall look and quality of each map is related to its purpose. The original purpose for the Mercator Projection in 1569 was clearly stated on the map: "A new and Enlarged Description of the Earth with Corrections for Use in Navigation." The Mercator was created to show places in relation to one another, not necessarily accurately in all respects, but correct for sailing purposes. The Mercator makes the latitude and longitude lines, and lines of constant bearing used by sailors, straight, so they can be used to chart courses and guide sailors across vast oceans. By this definition, the Mercator Projection was a great success, and can still be used for navigational purposes today. But is it a "politically correct" map?

The Mercator Projection is considered the most recognized of all world maps, mostly because it has been around for such a long time and was so well thought of by European navigators. However, the Mercator is well known today for its distortion of size, particularly near the poles. Its depiction of an enormous Greenland is a prime example. In fact, the Mercator has been perceived as purposely distorting land size in favor of the Northern Hemisphere, which takes up a disproportionate percentage of the map's overall display area. In particular, the Mercator has been perceived as distorting land size in favor of the Colonial Powers, by making the continents of North America and Europe seem much larger in relation to the rest of the world than they actually are.

In 1974, Arno Peters introduced the Peters Projection, a version of the world map that shows countries and portions thereof in more correct size perspective. The latitude and longitude lines are still straight, as they are on the Mercator Projection, but the size relationships between countries are less distorted. For that reason, the Peters Projection is seen as a more fair depiction of countries in the Equitorial regions. However, the Peters Projection noticeably distorts the familiar shape of each land area, making some continents appear stretched and elongated.

Several unusual and intriguing views of the world are presented on the pages that follow this discussion, including a map centered on the City of Toronto. At first glance, it appears that the reader is looking down at a section of the Earth from high above, with Toronto, Canada at the center of the sphere, and what appear to be "latitude" lines moving outward from Toronto like ripples on a pond (these lines are actually measures of distance). This is an Azimuthal Equidistant Projection, which is designed to show accurate distances from a central point (in this case, Toronto). The shapes of the continents are distorted again, as on other projections, and the distances between locations are only accurate if Toronto is the starting or ending point. But once again, this map serves the purpose for which it was designed: determining distances between Toronto and other world cities.

Another interesting view of the Earth is the 1927 Buckminster Fuller "Spaceship Earth Map," also known as the Dymaxion World Map. This map looks rather like a puzzle that begs to be folded and assembled into some kind of whole, with triangles, trapezoids and parallelograms all extending from a central plane of sorts. In fact, *Life* magazine even published it as a cutout in 1943. No significant distortion of land size or shape is noted, but because of the unique way the map is presented, there is no clear indication of north or south, and it does not purport to offer accurate distances. The purpose of the map is to present the world in a more reasonable fashion, without the perceived prejudices of the Mercator Projection. It succeeds in a very unique way, yet it has never enjoyed widespread acceptance or popularity in cartographic circles.

The National Geographic Society has used three different map projections since 1922 to represent our Earth in their publications. From 1922 to 1988, the Van der Grinten Projection was used because it showed a familiar, Mercator-like map that had less distortion and appeared in a circular format resembling a flattened globe. Also, the Van der Grinten provided some of the preservation of land mass shape that is lacking in other projections.

From 1988 to 1998, Arthur Robinson's Projection was used. The Robinson Projection can be centered on North America or on Africa, as needed, and shows less distortion than the Mercator or Van der Grinten. The world is presented as an elongated sphere, rather like a globe that has been longitudinally dissected and unwrapped; and, as such, it looks good to the eye.

The Winkel Tripel Projection was originally created in 1921, yet not used by National Geographic until 1998. This map is thought to provide less overall distortion than the two previous projections, while still retaining relevant shapes for all land masses. Like the Robinson, the Winkel Tripel is also displayed as an elongated sphere. National Geographic cites the less distorted depiction of Greenland on this projection as a prime reason for making the switch.

Seeing Through Maps also explores the concept of the "upside down" map, using the "What's Up? South!" Map as an example. This projection shows the world with south on top, or "up," as opposed to the projections we are most used to looking at, which show north "up" and south "down." McArthur's Universal Corrective Map of the World, created by an Australian student tired of hearing his homeland referred to as "Down Under," is another projection that shows the world (and Australia) with south "up." Yet another variation on this theme is a Lambert's Azimuthal Projection that shows the Earth centered on the North Pole, so everything, "up" or "down" on the map, is actually south.

An intriguing and unusual concept in mapping is the cartogram. The geographic locations shown on a cartogram are not based on their true shapes at all, but on typically non-visual factors, such as overall population. Looking at a cartogram of the Earth, the continents and countries are barely recognizable, since the size of each country is made larger or smaller in accordance with its overall population. However, the population data is clearly conveyed, and comparisons between locations can be easily made.

Maps that provide information without true geographic reference are also shown, including a familiar map of the London Underground, or subway system. This "map" consists only of lines spreading out in all directions, each representative of a rail line, with the names of the corresponding subway stations listed in order along each line. This map is not scaled or otherwise geographically correct, but it serves its purpose by providing information the average subway rider needs in an easy-to-follow format.

The book is supplemented with two appendices. Appendix A offers ideas for using various map projections in education. Appendix B provides a table of the most commonly used map projections and briefly describes the pros and cons of each one. A complete list of illustrations and a brief chronology of map development are also included just before the index.

A companion DVD, "Many Ways to See the World," is also available. It includes a half-hour documentary about the many ways we look at the world through maps. The documentary is basically a PowerPoint presentation and summary of *Seeing Through Maps* as done by Bob Abramms, one of the authors. He vividly displays the difficulties inherent in making a flat map out of our round Earth by showing how hard it is to peel an orange and then get the peel to lie completely flat. He proceeds to discuss the pros and cons of many map projections in that same context.

The DVD also includes a PowerPoint biography of Arno Peters, creator of the Peters Projection; the PowerPoint slides from the documentary presentation given by Bob Abramms; a PowerPoint presentation on the Peters Projection; information about a forthcoming book from ODT on the Peters Projection; radio interviews in MP3 format; and various PowerPoint slides showing map projections featured in *Seeing Through Maps.* Schools and non-profit organizations have the option of purchasing the DVD with reproduction and distribution rights.

I couldn't help thinking, as I learned more about the Mercator Projection through both the book and the DVD, that Gerardus Mercator would relate well to the GIS mapmakers of today. He didn't create his map projection to be taken literally as the definitive view of the world, as his "disclaimer" clearly indicates. He created it "with corrections" to be used for navigational purposes only. Yet the Mercator Projection has been misconstrued for many years as a "true" image of the world we live in. Similarly, many people in today's world mistakenly look at a digital map as a definitive view of the area it represents. Because a digital map is created by computer, it is perceived somehow as gospel, and map users do not always bother to consult the disclaimers and metadata to determine its "true" level of accuracy or intended use.

In referring to any map, whether hand drawn or digital, *Seeing Through Maps* reminds us that it is important to understand why a particular map was created in the first place and to use it accordingly. The computer allows us to take certain liberties with a digital map, such as zooming through multiple scales, that can have far reaching consequences if we forget why the map was originally created. Enlarging the geographic image may provide the illusion of greater detail, but it does not change the level of accuracy associated with the map's original scale and purpose.

The overall intent of the book, as well as the companion DVD, is to get readers to look at as many different points of view as possible regarding images of our Earth or portions thereof. Readers are encouraged to believe that no single map is completely correct or completely wrong. It depends on what a map is made for whether it succeeds or not. Through the liberal use of illustrations, readers are given the chance to note the pros and cons of each map projection, and/or to see how well a particular map suits its original purpose. The following key statements from the book's first chapter sum it up nicely:

Every map is a purposeful selection from everything that is known, bent to the mapmaker's ends. Every map serves a purpose. Every map advances an interest.

With three diverse authors contributing to this book, it seemed that each one had a collection of images and thoughts that he believed would best underscore the previous statements. This need for mutual expression occasionally caused a line of reasoning to be dropped unexpectedly and then picked up again somewhat later in the text, as if one author had stated, "That reminds me of a story," and proceeded to interject it, while another author waited patiently to return to his original point. Although I feel that the book tends to move back and forth between subjects excessively at times, it ultimately fulfills its mission.

I would very rarely make this statement regarding a movie made from a book, but I felt that in some ways, the companion DVD was actually the superior of the two. The lecture by Bob Abramms on the DVD makes what I felt was a more cohesive presentation of the key elements in the book, taking viewers systematically through the parade of map projections and other images in order to reiterate that each serves a specific purpose. Since Bob Abramms' occupation involves the development of management training materials and seminars, this was not surprising.

The DVD also offers tremendous educational materials that can be used by schools and non-profit organizations. The PowerPoint imagery alone could be easily adapted to a variety of presentations and courses. However, if it is possible to add both the book and DVD to your collection, I would definitely recommend it. The book offers some important guidance for educators that the DVD alone does not.

Many people in the civil engineering industry in which I work are looking at cartographers and GIS professionals as little more than data processors or printing clerks these days. I strongly disagree with this assessment. The aptly titled *Seeing Through Maps* and its companion DVD remind us that maps are very powerful tools with an ongoing influence on world events and popular culture that is virtually unsurpassed by any other means. There are as many different maps as there are viewpoints, and their power is in the hands of the person or group whose needs and vision they most fully convey.

Mapping: Methods & Tips

Achieving Historical Map Effects with Modern GIS

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Introduction

Historical maps have long captivated map readers with their aesthetic qualities and the intrigue they impart, partly because they were done by hand. In this paper, historical maps were examined to determine if they illustrated design techniques and symbology that are adaptable for maps today. If so, the design techniques were then replicated in a modern map making environment using geographic information systems (GIS). With this "history of cartography" approach, we attempt to discover the underlying technical process of creation.

One might ask why anyone would want to do this when cartographers now have better tools (*e.g.*, computers) to produce maps in greater quantities, with more consistency, with higher accuracy, and (arguably) with greater efficiency. One answer would be that though there are better mapping tools, that does not necessarily mean there are better mapping techniques; however, there really is more to it than that. Firstly, the symbology and mapping techniques on historical maps could be used to enhance the affective design, that is, "the look and feel", of maps made today. The use of these techniques does not necessarily result in period reproductions. For example, a parchment fill and a special font could be used to promote a more freeform, hand drawn albeit modern and artistic affective design.

Secondly, in some cases, using these techniques and symbology can actually improve the effectiveness of maps. For example, one technique for creating a coastal vignette using horizontal dashed lines, or "coastal rakes", was used historically because it was difficult to achieve fine gradations of ink. Today, with half tones, this effect could be easily achieved by substituting color for line-work. The historical coastal rake technique is useful today for black and white maps and maps intended for photocopying where fine gradations of ink are difficult to achieve and reproduce. As another example, pictorial symbols, such as hillsigns or town and building symbols may be easier and more intuitive for quick map-reading when a user is looking for landmark features. Maps do not always require detailed terrain and cultural feature depictions; instead it may be more useful to provide a stylized caricature of key landmarks.

Finally, the symbology and design techniques described in this paper can be used to make maps that are more eye-catching for the map reader. The reader is drawn to the map and the map holds the reader's attention longer because of the increased novelty, beauty, and density of information on the map.

As regards novelty, creating maps using fonts and symbols that differ from the status quo offers the opportunity to produce unique and visually arresting designs. Uncommon yet appropriate fonts, symbols that are new to the reader, and decorative borders or cartouches create a fresh look, despite their historic ancestry.

As regards beauty, the map effects described in this paper are designed to be pleasing to the eye. Many people are familiar with the effects (e.g., cartouches, ocean art) through casual if not calculated knowledge of historical maps. A hand drawn look with slight variations in the symbology (e.g., slightly varying line widths, watercolor fills, and curves that are not perfectly round) mitigate the cold "machine" look that computers cannot help but render. Understanding this appeal, software companies are now starting to package tools to achieve such effects in their software, and GIS software has new functions that also produce some of these effects. For example, the wave geometric effect (an ArcGIS Developer's Sample for use with cartographic representations) modifies rendered straight line segments so they have sinusoidal curves.

As regards density of information, the old-style symbols add complexity, information, and detail to the map. Pictorial symbols are more complex and detailed than their more abstract yet uncomplicated geometric counterparts, such as circles or squares. Pictorial symbols carry meaning that is more immediately understood by the reader since the symbol is intended to mimic the feature it represents. "Mimetic symbols are desirable on maps when they are unambiguous and easy to understand" (Robinson, et al. 1995). Mimetic symbols can be used to represent either quantitative or qualitative variation in the attribute being mapped. For example, town symbols can be used to represent quantitative variation in the amount of population, while different hill symbols could be used to distinguish among different qualitative types of physiographic features, such as mountain ranges, volcanic cones, rolling hills, high peaks, etc.

Cartographers can learn from historical maps to improve aspects of modern maps. What visual effects are evident on historical maps? What techniques were historically used to create them? How can they be replicated or improved using modern data and technology? Do the effects actually improve the design of modern maps? And, can the techniques be used to improve the map production process? In this paper, these questions are explored and the conclusion is that some effects can be replicated, some results are better than others, and some require data manipulation and data processing. The closing sentence – don't they all require data manipulation and processing?

This paper is organized by three rough time periods: the late sixteenth to early seventeenth century, the early to mid-nineteenth century and the late nineteenth to early twentieth century. For each, a map was created to test the development of some of the cartographic effects found on maps from the associated time period. Selected cartographic effects that could be replicated using computers and GIS are then described and illustrated.

Late Sixteenth to Early Seventeenth Century

A Caribbean Sea map was created to develop and demonstrate techniques found on maps from the late 1500s to early 1600s. On the Caribbean Sea map (Figure 1), the cartographic techniques explained in further detail include the following.

A. Hillsigns used to symbolize physiographic features such as mountain ranges and hills.
B. Coastal rake used to symbolize the shoreline areas.
C. Decorative north arrows connected by rhumb lines (lines of constant bearing).
D. Various illustrated map surrounds, including the ocean art, such as ships and sea serpents.

Hillsigns

Denis Wood (1992; 153) termed the mountain symbols that depict physiographic features "hillsigns" (Figure 2). These symbols were applied to point GIS data with an attribute that was added to distinguish the type of landform. Physiographic features were classed into fourteen categories based on their names, but other classification methods could be used. Each feature type was assigned a slightly different hillsign. Some features were assigned symbols composed of groups of hillsigns; these were used for physiographic features such as mountain ranges and ridges

Coastal Rakes

Coastal rakes (Figure 3) were used as an alternative to the more commonly seen coastal vignettes that use graded colors. One advantage is that while historical maps had to be laboriously etched or engraved and then painted, all by hand, these methods can be replicated quickly and easily with GIS. Both effects can be achieved using either constant or variable width buffers; the difference lies in how the buffers are symbolized. The coastal rake effect is achieved by symbolizing the buffers with fill patterns composed of a set of dashed lines each with different irregular spacing for the dashes.

Figure 4 illustrates variation in one of the line symbols that were created for the Caribbean Sea map. A variety of fill patterns were created for the various buffers on the Caribbean Sea map, with near-shore fills composed of more closely spaced dashes.

Rhumb Lines

For rhumb lines, the north arrows were used to digitize lines as GIS features connecting points of equal bearing. Because the lines are GIS features, they can be placed under the land masses, helping to promote figure-ground (Figure 5).

Ocean Art

On this map, there is also decorative ocean art, including ships and sea serpents (Figure 6). These were created as marker symbols placed in a focused data frame. In other words, the point symbols were added to the map as graphics that are spatially referenced to the geographic data.

The symbols for the ocean art were created as drawings and saved as image files in Enhanced Metafile or .emf format. In the GIS, marker symbols were created as picture marker symbols based on the .emf files (Figure 7).

These types of marker symbols can be created so that they are angled to rhumb lines in a Mercator projection. This is done by defining in the drawing software the angle of the image at the origin point as the degree of the rhumb line. An example is the cherubs in Figure 8 puffing wind to indicate the various compass directions.

To see how some additional effects found on maps from the late 1500s to 1600s could be achieved, a map of England was created, then a larger scale map of Devon and Cornwall was compiled (Figure 9). Design effects on the Devon and Cornwall map that are explained in further detail include the following.

A. Cultural features such as cities shown with mimetic symbols.
B. Stippling for the ocean fill.
C. Wide tapered streams.

Mimetic City Symbols

The cities were symbolized using mimetic point symbols. Five symbols were created for five classes based on city population. The various symbols were assigned to the five population classes. In the GIS, these marker symbols were created as character marker symbols that reference glyphs in True Type fonts. One advantage of referencing font characters instead of image files (as was the case with the ocean art in Figure 7) is that the multiple layers in the symbols can be easily colored separately (Figure 10). Another advantage is that scalability of the vector font is usually superior to the scalability of an image in the marker symbol.

Ocean Stippling

The stippling in the oceans areas was created using a dotted fill pattern placed over a parchment fill (Figure 11). The parchment fills and stipple pattern were created as .emf files. These were then combined in a multi-layer picture fill symbol.

Stream Tapering

Another design technique that was replicated with GIS was stream tapering. This was achieved using "representations" which is a new software enhancement in ArcGIS 9.2. The taper geometric effect creates polygonal symbology from linear input geometry; the fill symbol changes in width from one end of the line to the other according to values chosen by the cartographer. The tapered stream effect will be available as a download from the ESRI Support website

Early to Mid-nineteenth Century

To test the development of some of the mapping methods from the early to mid-1800s, the map of Devon and Cornwall was further modified (Figure 13). This map contains many of the design effects described above; additional techniques described in detail include the following.

A. Symbology for the populated areas using building point symbols placed alongside roads.
B. Use of a decorative border calibrated to the graticule.

Point Symbols along Roads

The effect that was used to symbolize building points alongside roads was driven by GIS data processing (Figure 14). First, the city areas were buffered using three different size buffers based on population. These buffers were used to clip the road lines so that it was possible to identify where to show the building points – that is, where the roads ran through populated areas. The line symbol was created with two layers – one for each side of the road. Each of the layers was offset to one side of the road, and a marker line symbol with staggered points from a different template was used. These line symbols were then placed alongside the cased roads in the populated areas only.

Border Calibrated to the Graticule

The calibrated border is actually very easy to replicate with ArcGIS – it is simply a property of the data frame, so if the data in the data frame is resizes or repositioned, the border will update automatically (Figure 15). This effect was created using a graticule border that was shown with a double line symbol, and the axis ticks were spaced and sized to fit between the double lines.

Late Nineteenth to Early Twentieth Century

To test the development of some mapping methods from the late 1800s to early 1900s, a map of Washington State was created (Figure 16). On this map, many of the cartographic effects described above are used, but the color palette is limited to a sepia tone. This would be useful for a limited color palette such as black and white map production or grayscale conversion.

Sepia Tone

The sepia tone effect was created using a number of methods. First, the data frame background was symbolized with a neutral parchment fill. Then the hillshade was symbolized using a dark to light-brown color ramp. Finally, the mapped area was highlighted using a transparent sepia-colored polygon fill for areas outside Washington. Together, these effects create a subtle map coloring that could be used to create interesting variation on the map even when the color palette is limited.

Conclusion

Many stand in awe of historical maps knowing that they were drawn by hand; they marvel at the detail and artistry involved. Maybe they also admire cartographers achieving the same or similar effects with computers. The advantage of a computer approach is that the precision and power of the computing environment can be used to deal with what computers handle best (data management and manipulation) and the cartographers can handle the things humans handle best (artistry and creativity). An additional advantage of using computer mapping techniques is that the flexible, repeatable computational power of the software allows map makers to relatively quickly achieve the results they want without having to spend countless hours on tedious tasks that could not be exactly replicated a second time if drawn by hand.

In this paper, historical maps were examined to determine if they offered techniques and symbology that could be adapted for maps today, and if so, how that could be done. Ten mapping methods were described, illustrating ways to reproduce some of the historical cartographic effects found on maps form the associated time periods. These methods can be integrated within the design tools of GIS to give cartographers additional ways to enhance modern maps.

The techniques described can help to improve modern design and production for a number of reasons: these enhanced effects allow greater design flexibility which is appreciated by both cartographer and map reader; some of the effects can be used for challenging black and white map design; some of the symbols are intuitive and easily understood by the map reader; some create a unique and unusual look that draws the map reader in and keeps his or her attention; and some add beauty and intrigue to maps. Of course, as with all maps, the effects should be used on the right type of map for the right purpose and the right audience.

Note

The ArcGIS styles shown in this paper, along with the maps, can be downloaded from the Basemap Data Model page of the ESRI Support Website (support.esri.com/index.cfm?fa=downloads.dataModels.filteredGateway&dmid=3).

References

Robinson, A.H., Morrison, J.L., Muehrcke, P.C., Kimerling, A.J., and Guptill, S.C. 1995. *Elements of Cartography*. Wiley & Sons. 674 pp.

Wood, D. 1992. *The Power of Maps*. New York: The Guilford Press. 248 pp.

Figure 1. The Caribbean Sea map by David Barnes (2006) illustrating A) hillsigns, B) coastal rakes, C) north arrows connecting rhumb lines, and D) ocean art.

Figure 2. Hillsigns used to symbolize various categories of physiographic features.

Figure 3. Coastal rakes used as an alternative to graded color coastal vignettes.

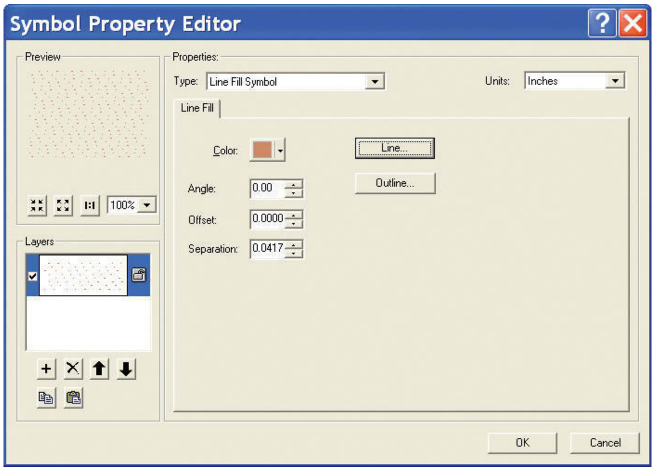


Figure 4a. Definition of one of the line symbols used for coastal rakes on the Caribbean Sea map.

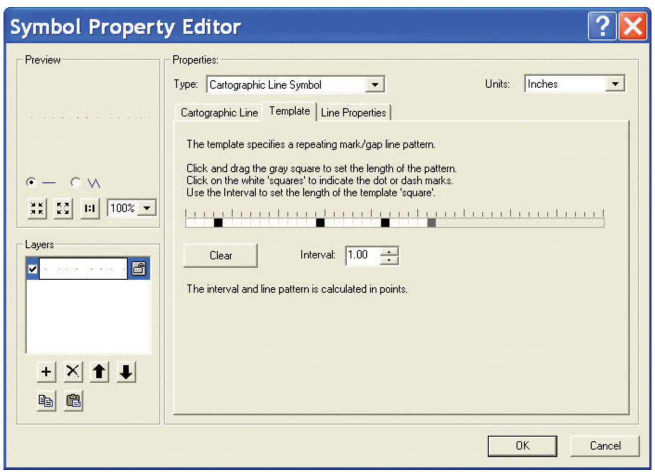


Figure 4b. Line symbol template.

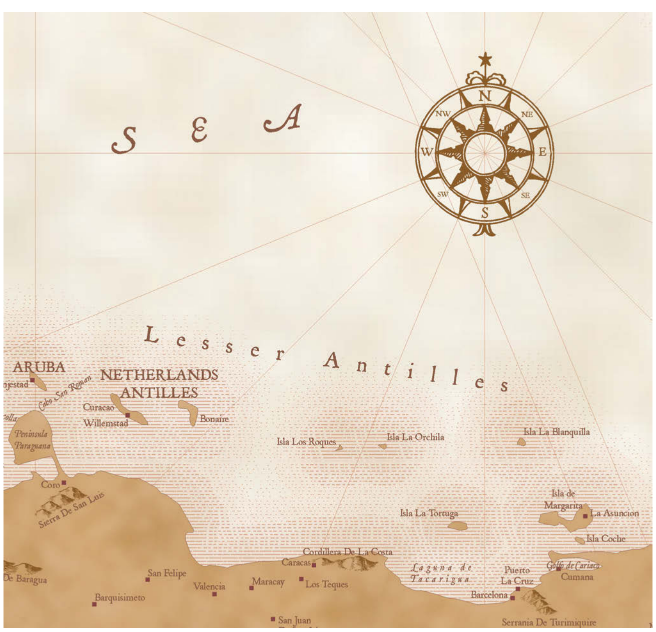


Figure 5. Rhumb lines are placed under land masses to help promote figure-ground.

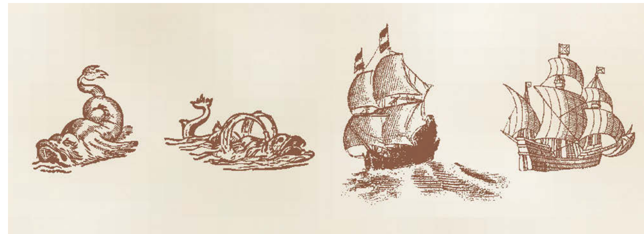


Figure 6. Various marker symbols were used to decorate the open ocean areas.

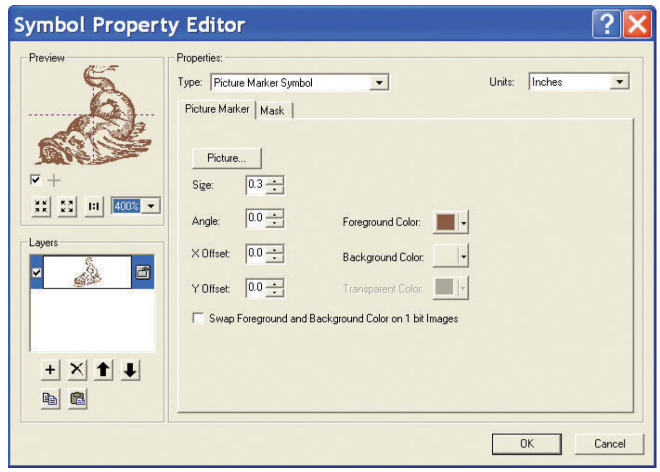


Figure 7. This sea serpent is a picture marker symbol that can be colored, resized, angled, and offset. A background color can also be set for the image.

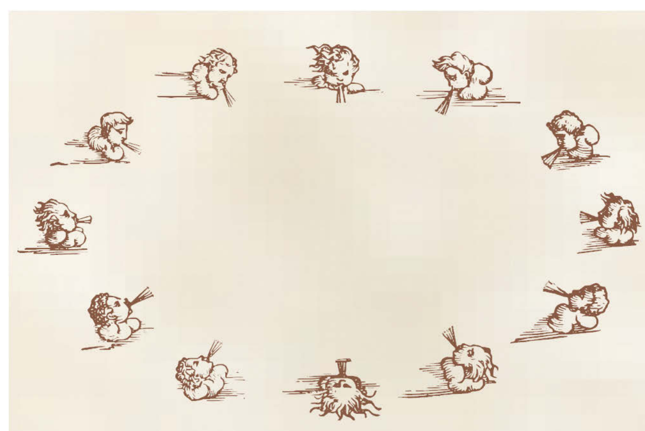


Figure 8. Windy cherubs can be used to indicate compass directions on a Mercator projection.

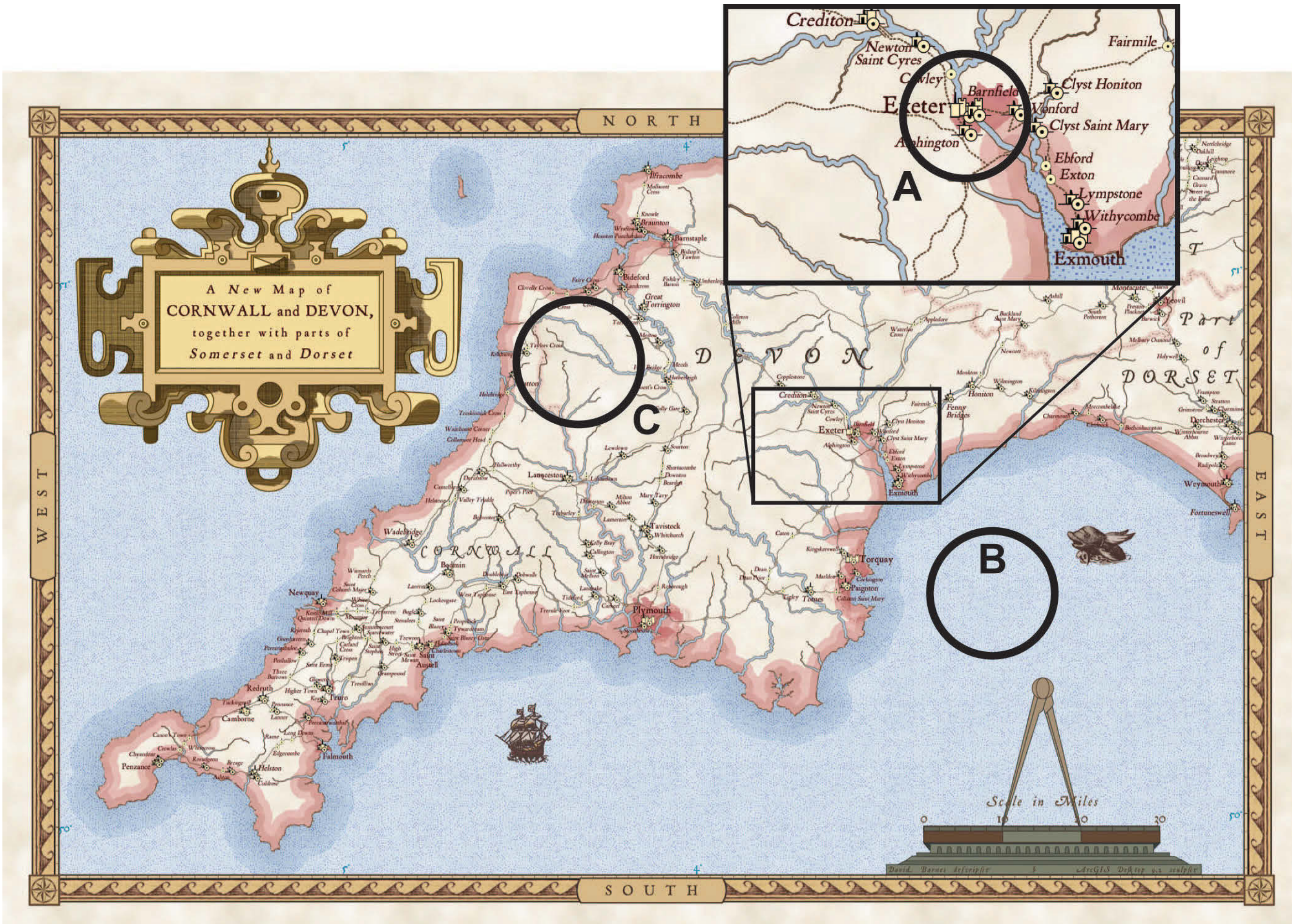


Figure 9. The Devon and Cornwall map by David Barnes (2006) illustrating A) mimetic symbols for the cities, B) a stipple pattern for the ocean, and C) tapered streams.

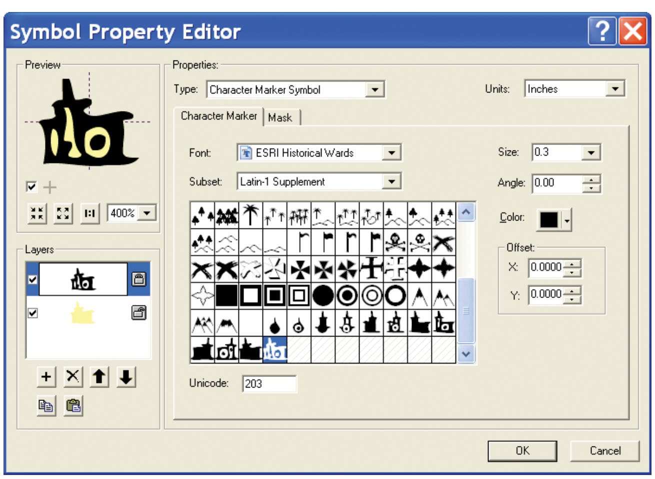


Figure 10. This city symbol is a multi-layer symbol. The top layer is colored black and the bottom layer is yellow.

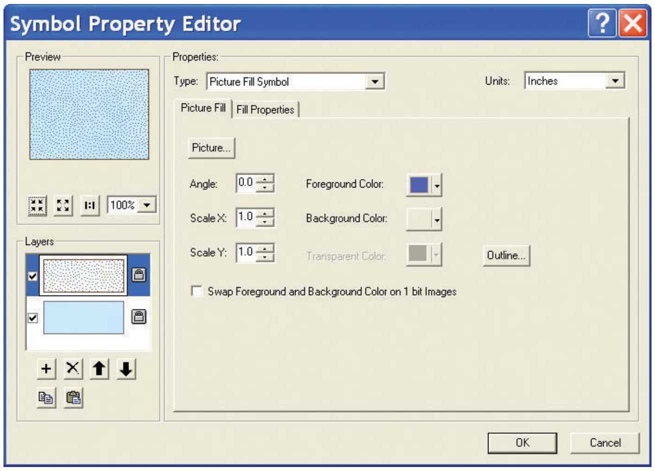


Figure 11a. This ocean fill stipple pattern is part of a multi-layer fill symbol. The layer is an .emf file.

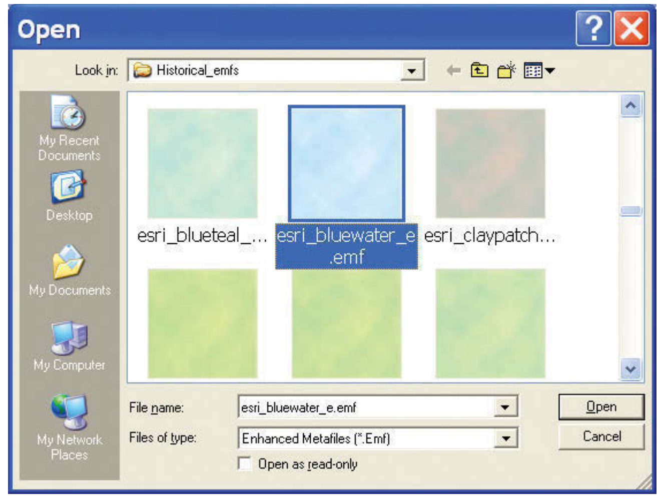


Figure 11b. Parchment fill for ocean stipple pattern. The symbol is an .emf image file.

Figure 12. Stream tapering is an effect that uses a fill symbol that changes in width from one end to the other for linear features.

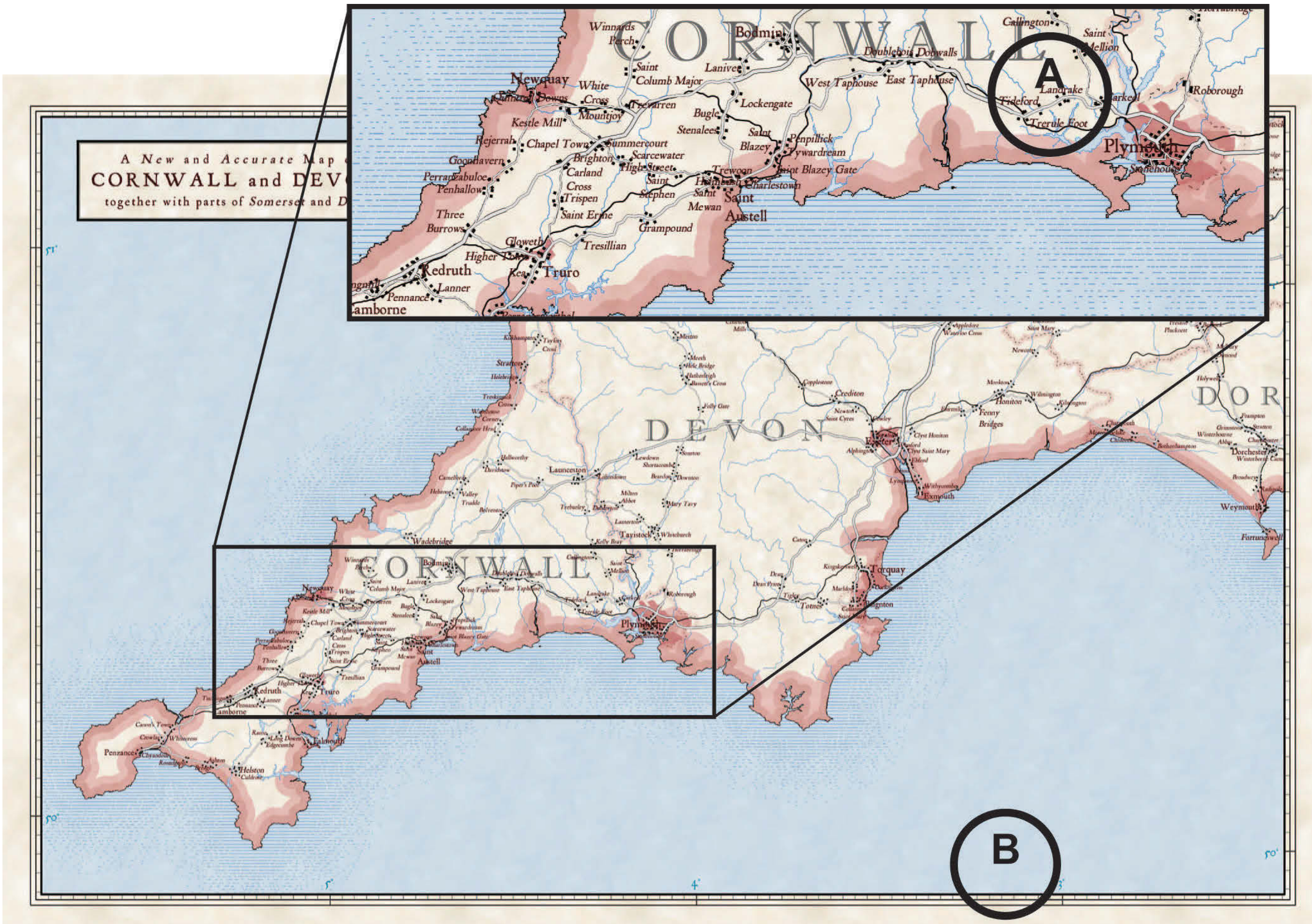


Figure 13. The Devon and Cornwall map by David Barnes (2006) illustrating A) point symbols placed alongside roads to symbolize populated areas and B) a decorative border calibrated to the graticule.

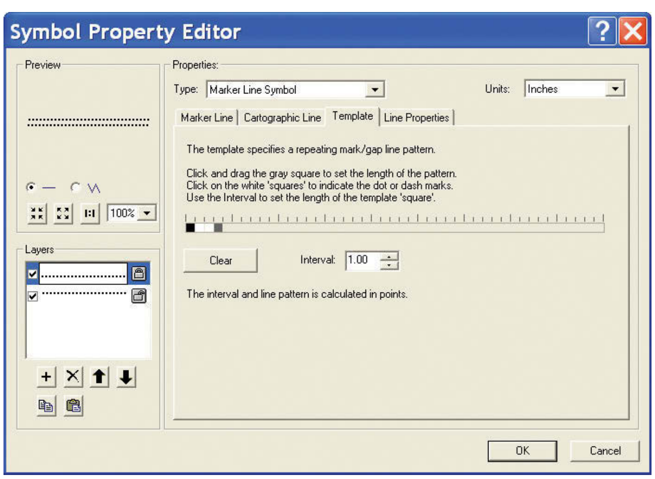


Figure 14. The building points were created as marker line symbols composed of two layers, each with a different staggering of points. Each layer was also offset to an opposite side of the road.

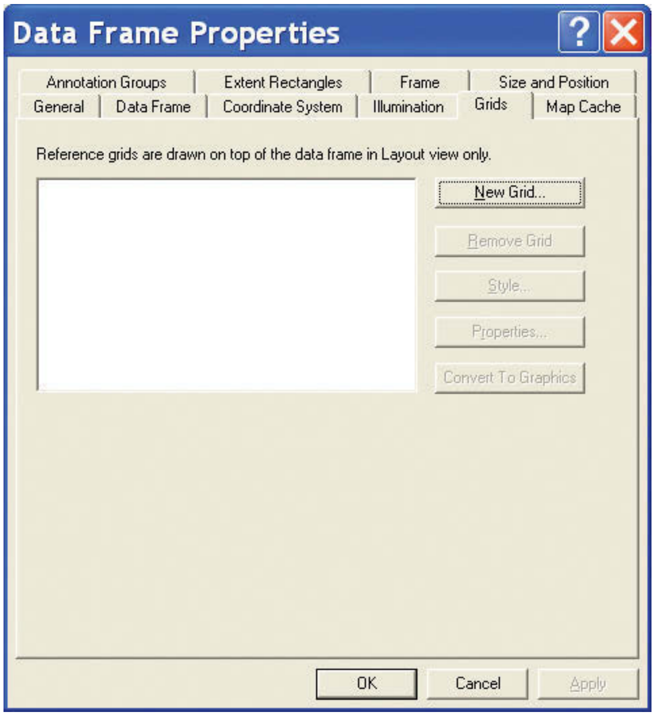


Figure 15a. A graticule grid can be used to create the decorative border calibrated to the graticule.

Figure 15b. Graticule grid wizard.

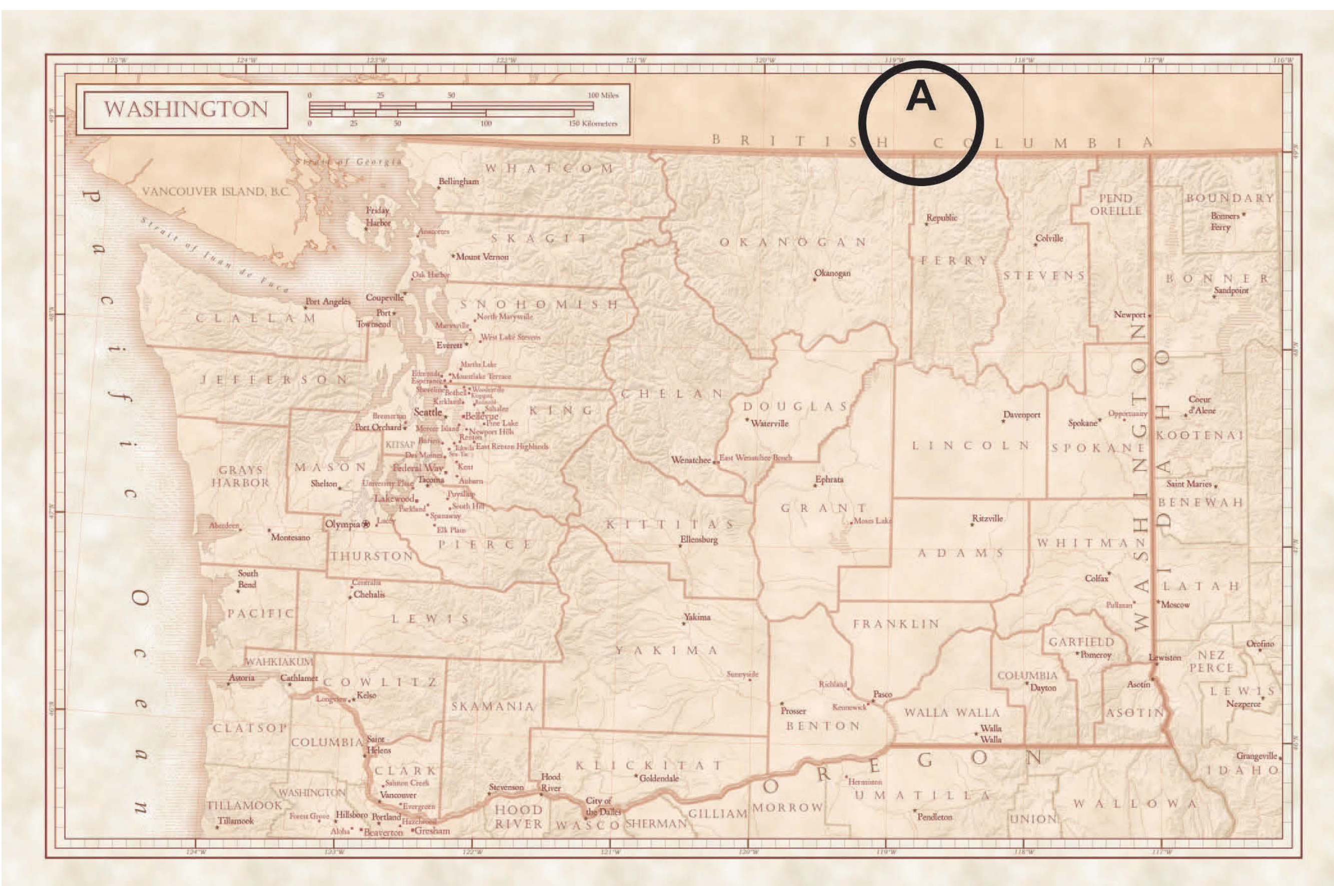


Figure 16. The Washington map by David Barnes (2006) illustrating A) sepia tones.

Color Figures

Visualizing Method-Produced Uncertainty in Isometric Mapping

Mathew A. Dooley and Stephen J. Lavin

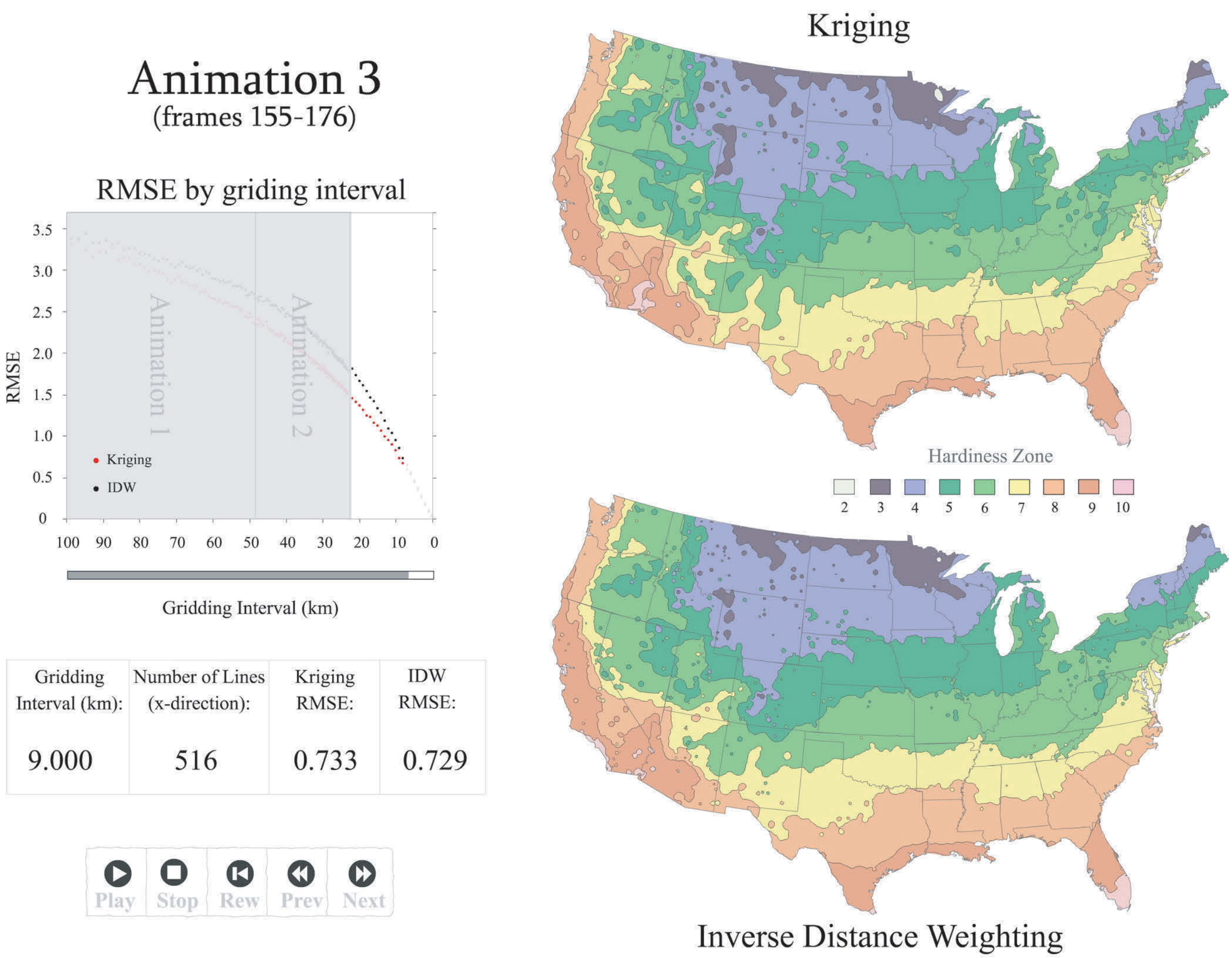


Figure 8. Screen capture of frame 169 of Animation 3 showing the difference in patterning for kriging and IDW when RMSE values are nearly identical.

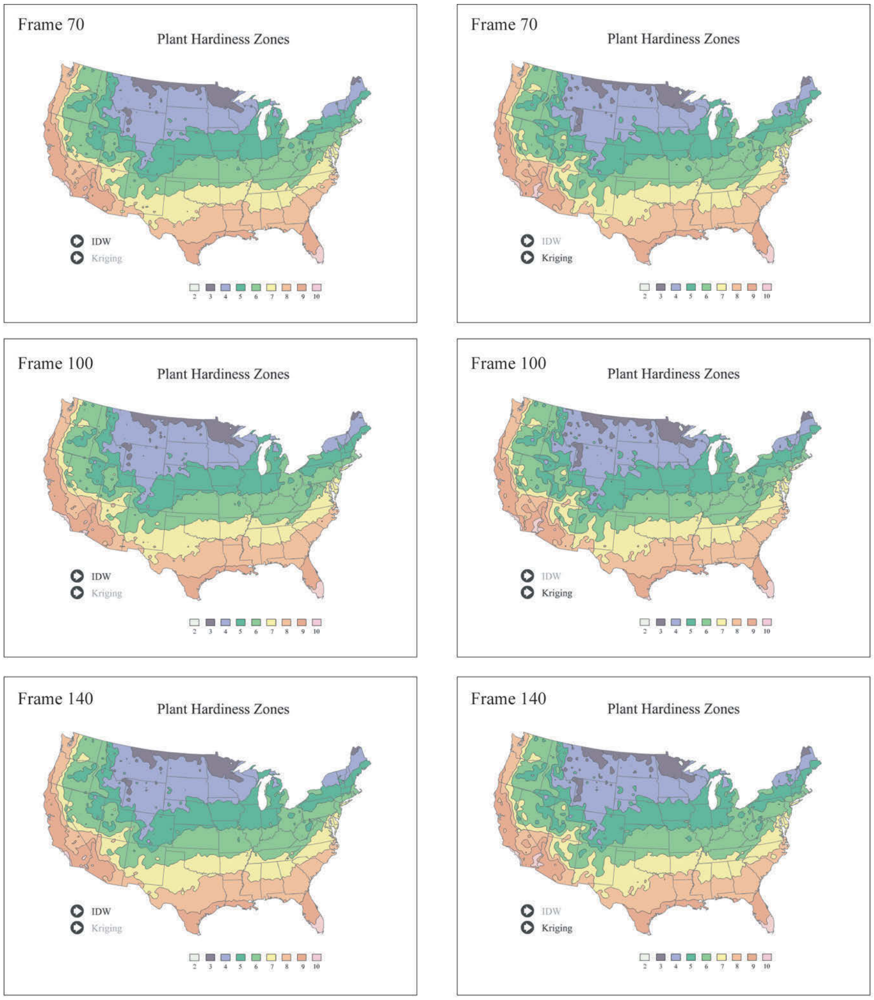


Figure 9. Selected frames from Animation 4. Frames on the left are IDW; frames on the right are kriging.

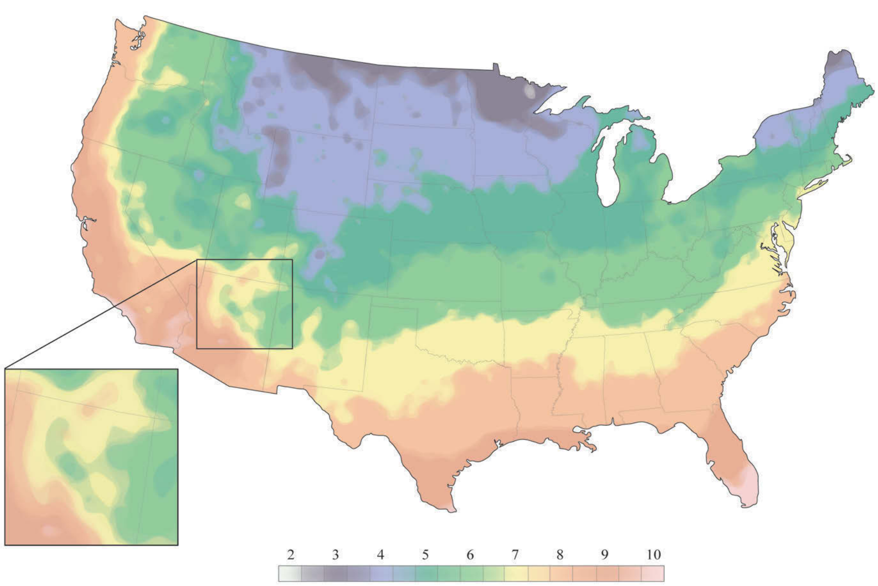


Figure 10. Composite map of 354 isometric representations of plant hardiness zones using kriging and IDW interpolation methods.

Visual Representations of the Spatial Relationship Between Bermuda High Strengths and Hurricane Tracks

Jason T. Knowles and Michael Leitner

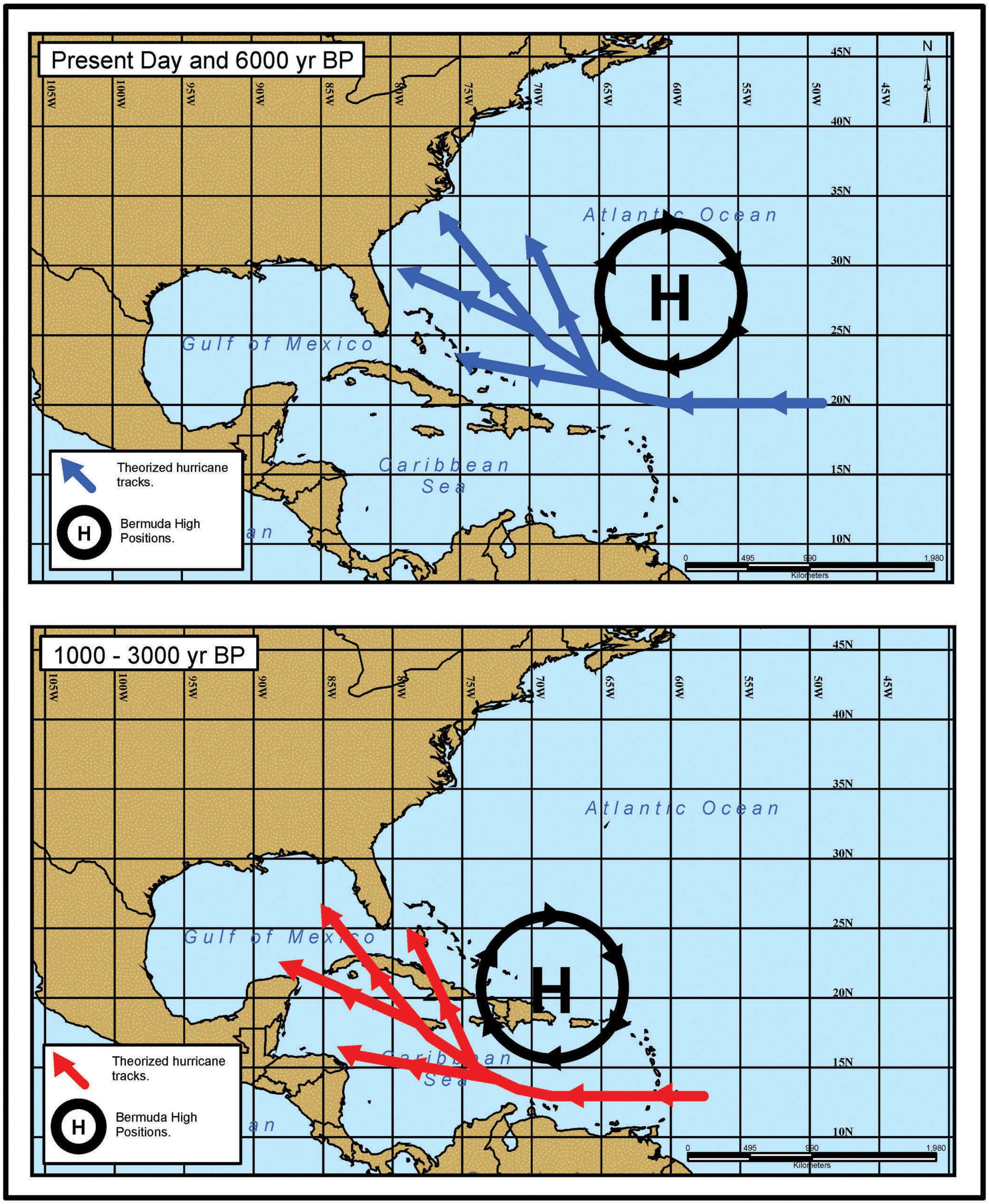


Figure 2. Relationship between the Bermuda High and hurricane tracks as expressed in the Bermuda High Hypothesis.

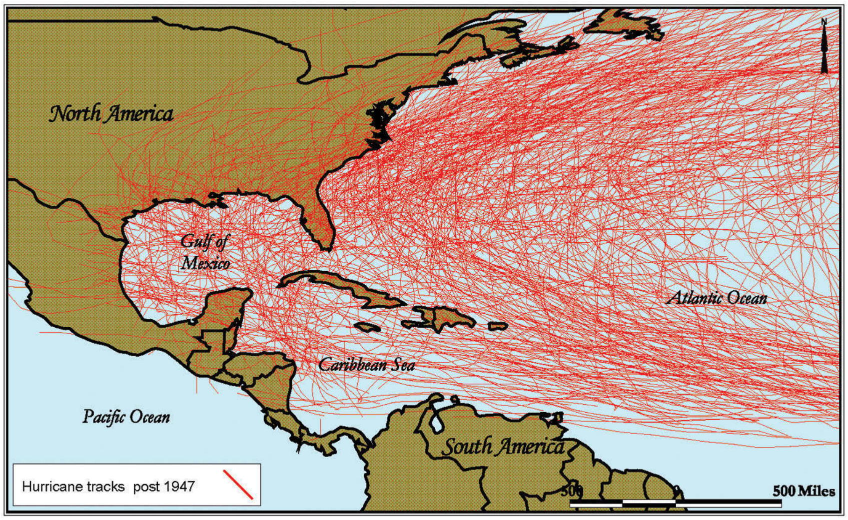


Figure 3. Visualization of all 577 hurricanes that have reached the Atlantic Ocean and the Gulf of Mexico since 1947.

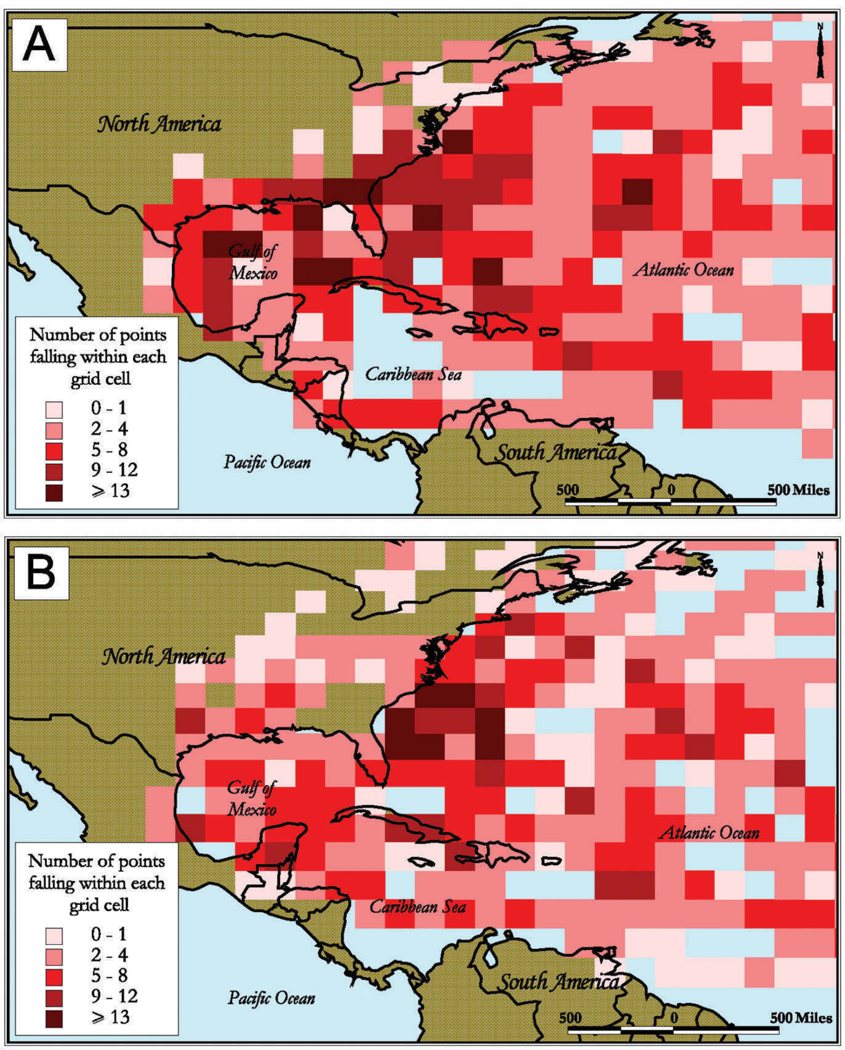


Figure 4. Choropleth mapping of hurricane density within a 2.5º latitude/longitude grid cell size based on a "weak" Bermuda High (4A) and a "strong" Bermuda High (4B).

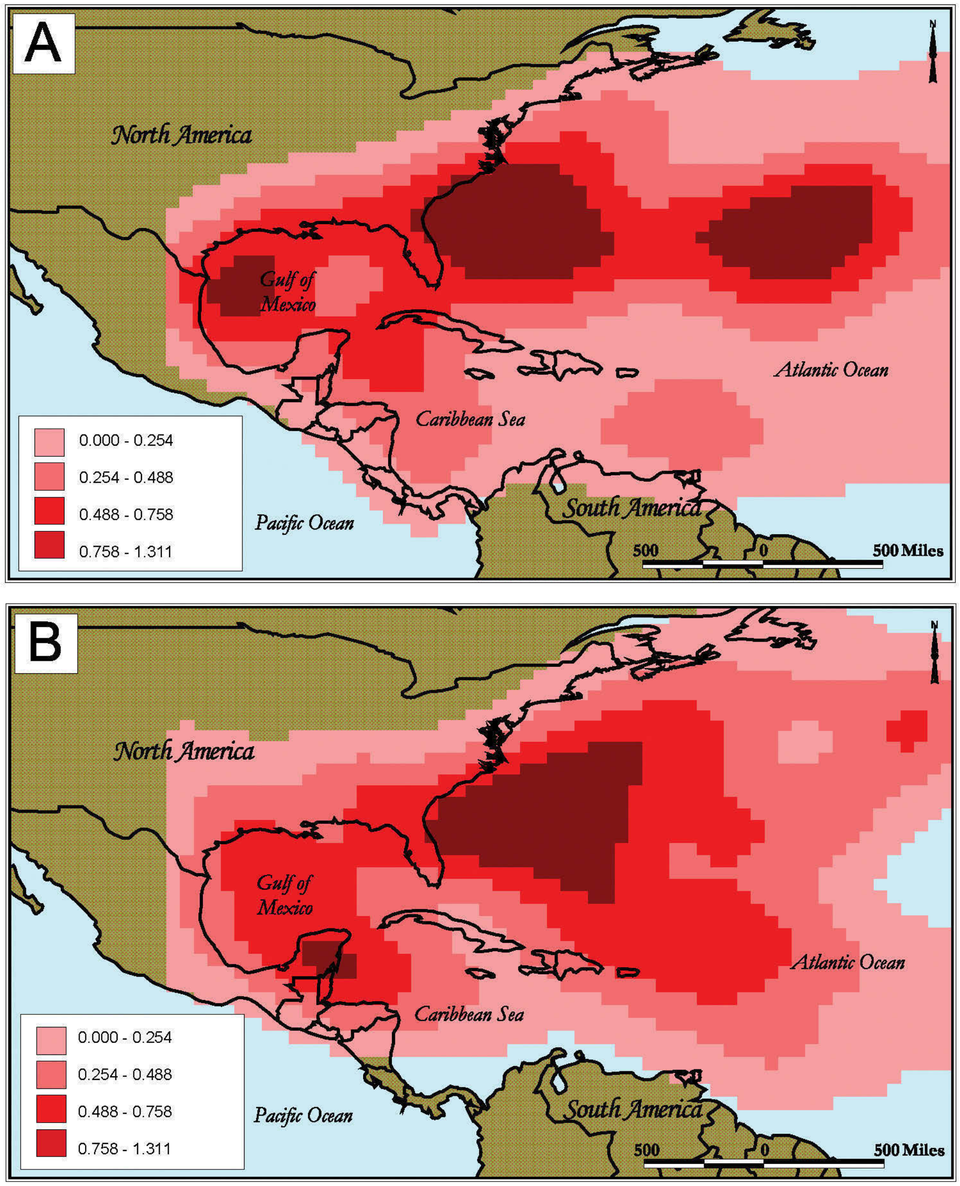


Figure 6. 2-D continuous surface display of hurricane tracks derived from kernel density estimations coinciding with a "weak" Bermuda High (6A) and a "strong" Bermuda High (6B).

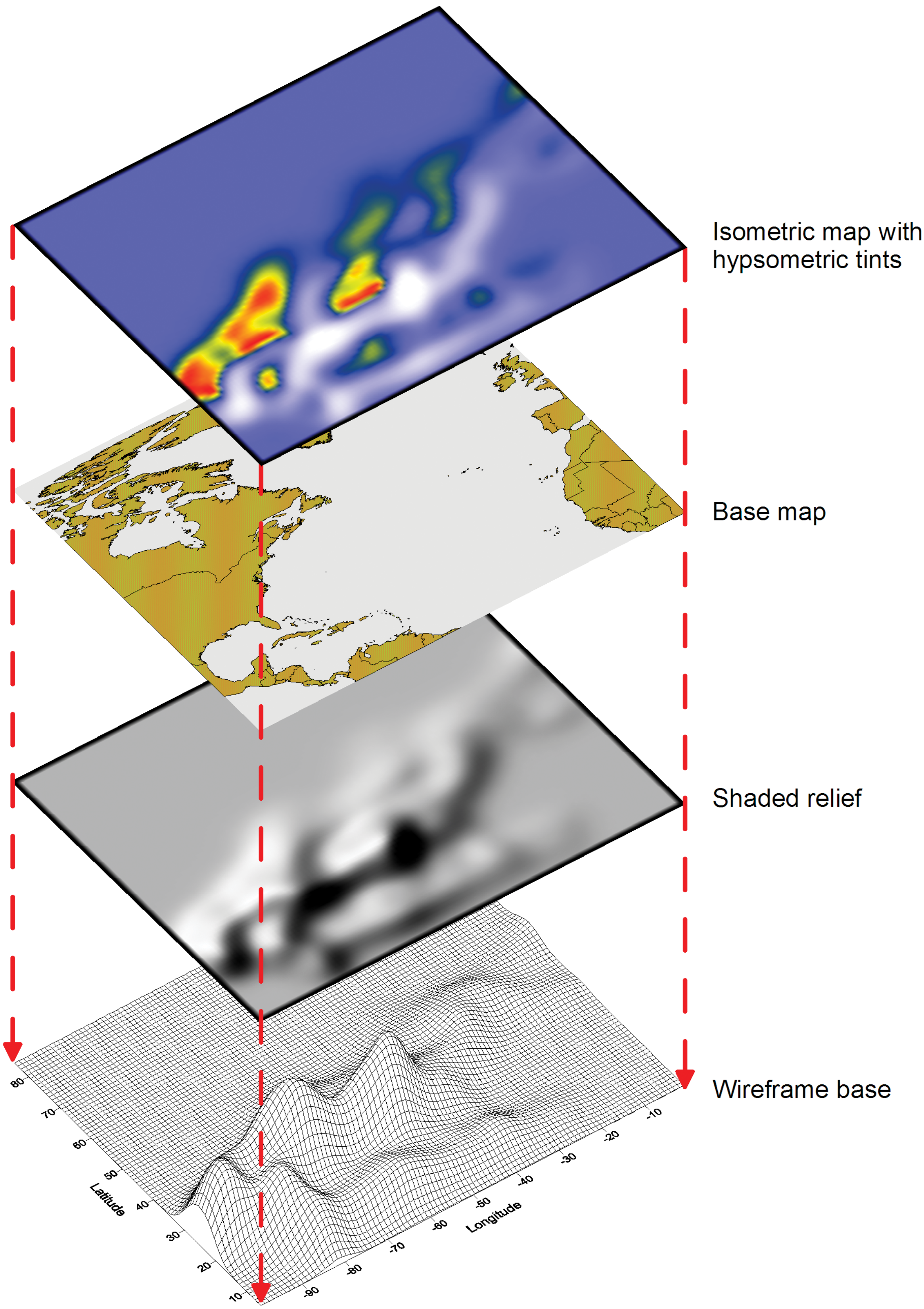


Figure 7. Schematic view of the components of the enhanced 3-D continuous surface display.

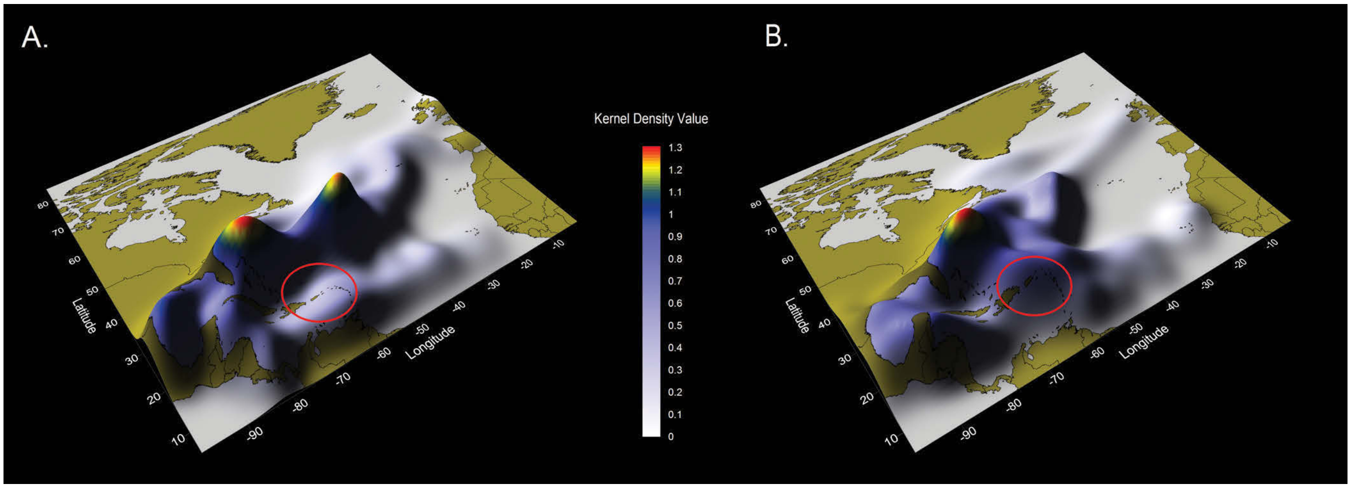


Figure 8. Enhanced 3-D continuous surface display of hurricane tracks derived from kernel density estimations coinciding with a "weak" Bermuda High (8A) and a "strong" Bermuda High (8B). Note: Red circles encompass the Caribbean Antilles and highlight changing risk associated with Bermuda High strength.

Visual Fields

Some Things Lilla LoCurto and William Outcault Have to Say About Maps

Denis Wood
Independent Scholar
Raleigh, NC

Lilla LoCurto and William Outcault, the artists whose *timeline_33seconds* graces the cover of this issue of *Cartographic Perspectives*, have a history with mapmaking, indeed with NACIS members, that goes back ten years. Until then LoCurto and Outcault had thought about themselves as sculptors, if sculptors of a distinctly modern cast. After all they had both graduated with MFAs in sculpture in 1978, and had taught and made sculpture during the following years. LoCurto tended to make room-sized installation pieces out of found objects. For example her *Crossings* (1991) used rows of white stretchers and sandbags in a piece about the first war in Iraq. Outcault, on the other hand, made organic abstractions out of wood, plaster, fiberglass, and lead. His *Untitled* (1991), for example, mounted six white, swelling organic forms on a cedar trellis.

LoCurto and Outcault began collaborating with *Self Portrait* (1992), a piece about the universal nature of the threat posed by AIDS. A room-sized, interactive, video installation piece *and* a convincing sculptural presence, *Self Portrait* incorporated characteristics of the work each had been doing. Four stacked video monitors in a chain-link cage hung inside a transparent globe nine feet in diameter. A network of tubes on the globe's exterior pulsated with a blood-like fluid synchronized to the pulse – the amplified sound of which filled the room – of the viewer who sat in a chair facing the monitors, on the top one of which appeared his or her head and shoulders. The lower screens displayed the constantly changing trunks, thighs, and legs and feet of others, so that the viewer's head sat on top of a protean, universal body, trapped in a cage hanging inside a transparent globe coursing with blood. The powerful piece traveled widely and was followed by others, *Sharp Appetites* (1994), *Vrouwke Pis* (1994), and *Bean Boys* (1995) that continued to pose questions about the human body, its fragility, its vulnerability, its fragmentation.

In 1996 LoCurto and Outcault attended a show about Buckminster Fuller's work where his icosahedral projection of the world hit them as something of an epiphany, revealing for them the sculptural implications of a map. "It was probably," LoCurto and Outcault have written:

> … the simplicity of his projection that made us understand what mechanics were involved but, like most people, we'd never really thought too much about how a map originated from a three dimensional surface. We saw connections between this and the artistic problem of rendering a three-dimensional object on a two-dimensional surface as well as with the Cubist and Futurist idea of simultaneity, experiencing that three-dimensionality at once in its entirety. We'd been working with the figure, particularly our own, prior to this and the idea of projecting the human figure like a map using digital technologies struck us as a way to add to these traditions in a contemporary way. We also imagined the process itself would contribute aesthetically to the final images by tearing the body as it flattened it, emphasizing the frailty and vulnerability we saw as inherent in our condition.

That is, mapping their bodies struck them as a powerful way to approach the themes that had been consuming them since *Self Portrait*.

But how to project the body? They began by attempting to use their flatbed scanner as a camera, hanging it upside down from a gantry and assembling the resultant scans into approximations of projections as one might do with air photos. They soon realized, however, that they needed a three-dimensional whole-body scanner to achieve the simultaneity they were looking for, which is the hallmark of any map. They found one at the Natick Soldier Systems Command in Massachusetts where they were invited in and scanned. They now had to find or develop software that could transpose the scanner output into maps. This search led them to John Krygier, then a geographer at SUNY in Buffalo, and Krygier introduced them to Daan Strebe, whose obsession with map projections had five years earlier led to the release of the map projection program Geocart. Strebe was willing to augment Geocart for LoCurto and Outcault but an interstial program was required to translate the scanner outputs into cylindrical and spherical coordinates, so Strebe introduced LoCurto and Outcault to the mathematician and sculptor, Helaman Ferguson. Ferguson introduced them to his mathematician son, Samuel Ferguson, and it was Samuel Ferguson who created The Body Mangler software that made it possible for Geocart to read the scanner output and produce the images that, realized as chromogenic prints mounted on aluminum, made up LoCurto and Outcault's *selfportrait.map* (1999). (There is a catalogue: LoCurto/ Outcault, selfportrait.map, Seattle: University of Washington Press, 1999.)

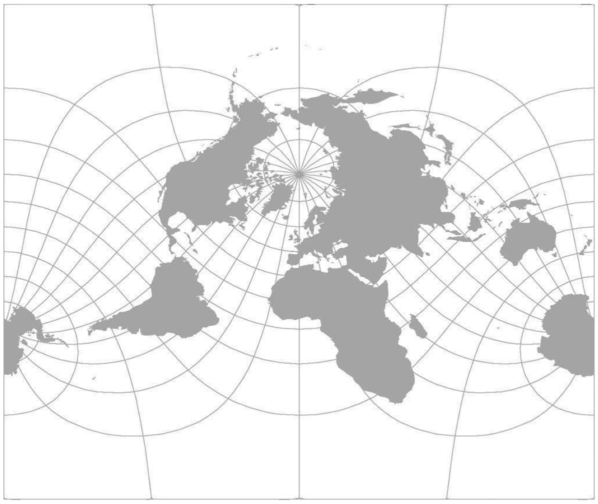
Of this suite of eighteen body maps we've reproduced five in our portfolio: *Bipolar Oblique BS1sph(8/6)7_98* (figure 1), *Gall Stereographic L8sph(8/8)7_98* (Figure 2), *Kharchenko-Shabanova BS1sph(8/6)7_98* (Figure 3), *Gall Stereographic BC-1sph(8/6)7_98* (Figure 4), and *Urmayev III L3sph(8/6)7_98* (Figure 5). This work is usually discussed in terms of the body, especially in terms of LoCurto and Outcault's concern for the fragmented, the fragile, and the vulnerable; but it is also seen as a revisioning of the self-portraiture tradition, and considered from the perspective of art history. For example, Helaine Posner has written of *Kharchenko-Shabanova BS1sph(8/6)7_98* (figure 3) that here "a photograph of William Outcault is symmetrically unfolded and splayed out across the

Figure 1. Bipolar Oblique BS1sph(8/6)7_98
1999
24″ x 24″
Chromogenic Print

Figure 2. Gall Stereographic L8sph(8/8)7_98
1999
48″ x 62.5″
Chromogenic Print

picture's surface, the body seemingly suspended in space. The central focus on his clasped hands and the tension between a body that appears to be drawn together and pulled apart brings to mind Michelangelo's *Creation of Adam* from the Sistine Chapel." Another critic has observed that, "LoCurto and Outcault's efforts result in a series of phantasmagorically rendered and printed images that are at once elegant and grotesque. They playfully blend a Botticellian sense of Renaissance/mythic grandeur with a post-modern fetishistic morbidity suggestive of Francis Bacon."

The images can, however, be read from other perspectives as well, for example, from that of the earth or that of map projections. After all, the earth and the body have long been seen as metaphors of each other and here, where the graticule is expressed, the comparison is almost unavoidable. To turn again to *Kharchenko-Shabanova BS1sph(8/6)7_98* (figure 3), Outcault's body is, as Posner noted, symmetrically unfolded and splayed out, but *exactly as the earth is symmetrically unfolded and splayed out* in this projection. The distortions which so fascinate and disturb critics looking at *Kharchenko-Shabanova BS1sph(8/6)7_98* are every bit as characteristic of the earth on such a projection, although the distortions of the earth have long since been confused with its actual appearance. Everything that can be said about the images of LoCurto and Outcault's bodies can be said as easily about the earth, including the reflections on fragility, vulnerability, and fragmentation, though again these have been conventionalized into acceptability. Who any longer sees, as on our map of the world here in the Kharchenko-Shabanova projection Antarctica *splayed*, the Pacific *severed*? The violence done to the globe by the map has been smothered by familiarity, but the images of LoCurto and Outcault recall us to a renewed awareness



of how cruelly the earth is *squashed* into a map.

Comparison of *Kharchenko-Shabanova BS1sph(8/6)7_98* with *Bipolar Oblique BS1sph(8/6)7_98* (figure 1), of *Gall Stereographic L8sph(8/8)7_98* (figure 2) with *Gall Stereographic BC1sph(8/6)7_98* (figure 1) should recall to mapmakers the genuine strangeness of the earth they so easily drop onto the page, should help them recover something of the marvelousness that projections embed in every map. Habit inures us to the wonder of the world. By defamiliarizing the thing we know best, our body, LoCurto and Outcault's work brings with it the possibility of reenchanting something we only *think* we know well, the earth.

Having taken this first step, LoCurto and Outcault found the next quite easy. On a subsequent visit to be

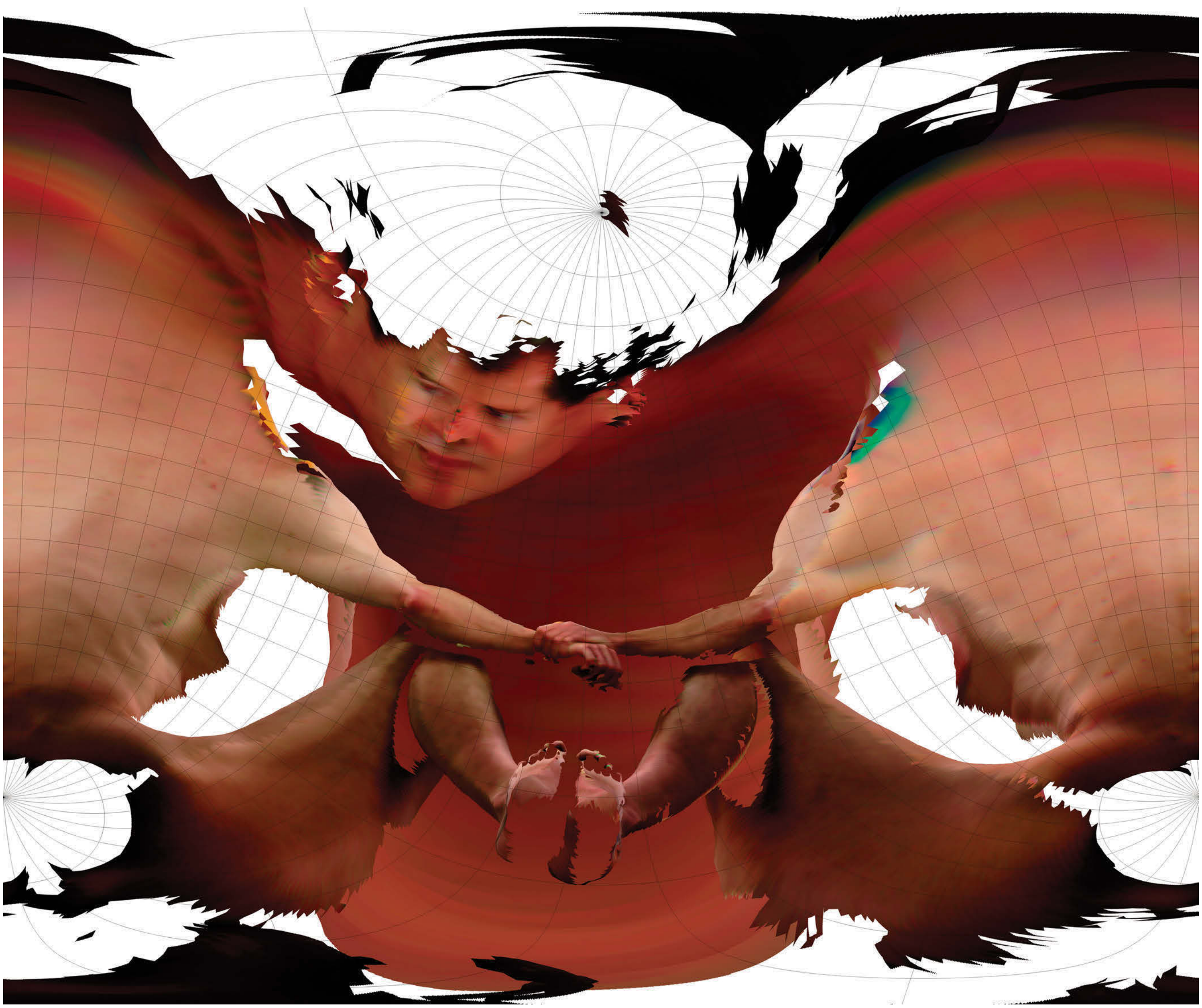


Figure 3. Kharchenko-Shabanova BS1sph(8/6)7_98
1999
48″ x 57.5″
Chromogenic Print

Figure 4. Gall Stereographic BC1sph(8/6)7_98
1999
48″ x 62.5″
Chromogenic Print

scanned at Natick they noticed in the software a utility that aligned the scanner's four laser views: "As the application traced the contiguous layers of our volumes," they write, "we were captivated by its description of the body as an almost liquid drawing. In one format the scanned data is expressed as parallel horizontal lines that describe the outer contours of the human figure. Points are located along each line with instructions on joining the adjacent points to create triangles, or polygons, which, when all connected, form a wire frame volume." Excited by the potential they saw here, they were able to enlist the aid of Neil Katz, an architect friend familiar with a proprietary architectural drawing program that could eliminate the points and vertices to produce line drawings. Sam Ferguson was then able to modify The Body Mangler so that LoCurto and Outcault could "topologize" this new body from any angle and into any number of layers. Of the resultant "topologies" we have reproduced *topo_bs1* (2004, figure 6). This is another version of the scan of Outcault mapped in *Kharchenko-Shabanova BS1sph(8/6)7_98* (figure 3) and, paradoxically, it's even more destabilizing. The contour-like lines seem to offer far more purchase on the image than was vouchsafed by the projected scan, yet any attempt to "follow" the lines leads to a realization that the figure is rendered inside out, an intuition that plays havoc with ones perception of the image.

Because of this, *topo_bs1* is capable of recalling to viewers their earliest encounters with contour lines, when their efforts to "understand" contours cognitively all of a sudden gave way as the lines "snapped" into a perceptual gestalt and sent them tumbling over the edge of the ravine or down the slopes of the mountain they were looking at. That sense of vertigo, especially acute when stereo pairs first come together,

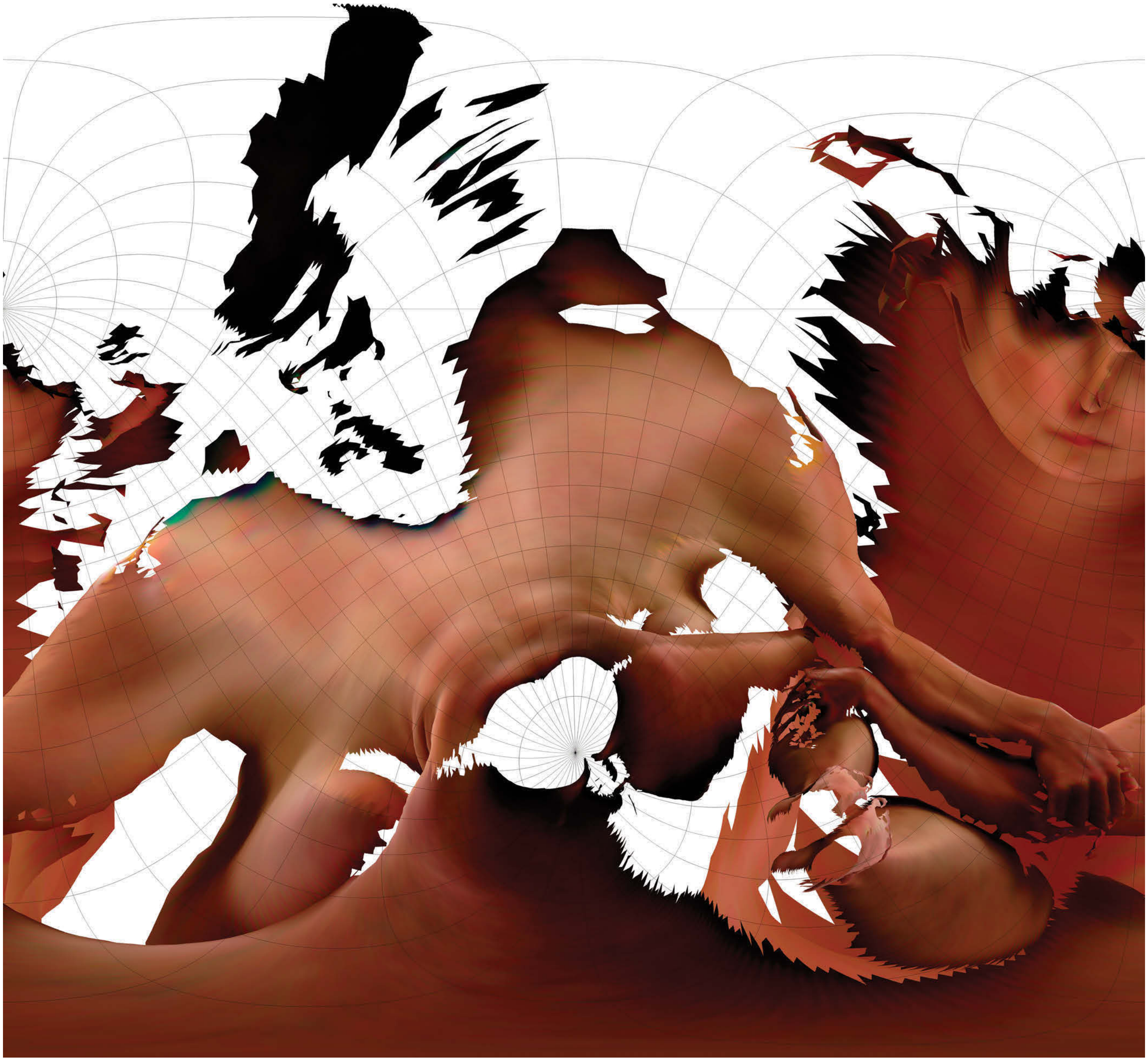


Figure 5. Urmayev III L3sph(8/6)7_98
1999
48" x 52"
Chromogenic Print

is a permanent attribute of *topo_bs1* whose paradoxes, however, no amount of looking seem likely to resolve. Nor have LoCurto and Outcault any interest in doing so. To the contrary, each step they've taken seems determined to further discomfit our sense of self. Further programming efforts on the part of Sam Ferguson and others, and later by Ferguson's younger brother, Michael Ferguson, provided LoCurto and Outcault with the ability to manipulate the horizontal layers individually and ultimately to animate them. This lead to an animation, *Essay of a Thousand Layers* (2003), and to the series *thinskinned* (2004) of which we have reproduced *thinskinned[b7]* (figure 7). Here the layers have turned into ribbons of flesh, and the body been dissolved into a handful of confetti. The software tool developed with Michael Ferguson, CuisinArt, has given LoCurto and Outcault even greater flexibility – they are no longer confined to ribbons but can slice and dice and recombine almost at will – resulting in the three-channel animation *scribble in the air* (2006) and the series *timeline* (2006) from which we selected our cover image as well as *timeline_20seconds* (figure 8) reproduced here.

While with these images we may seem to have

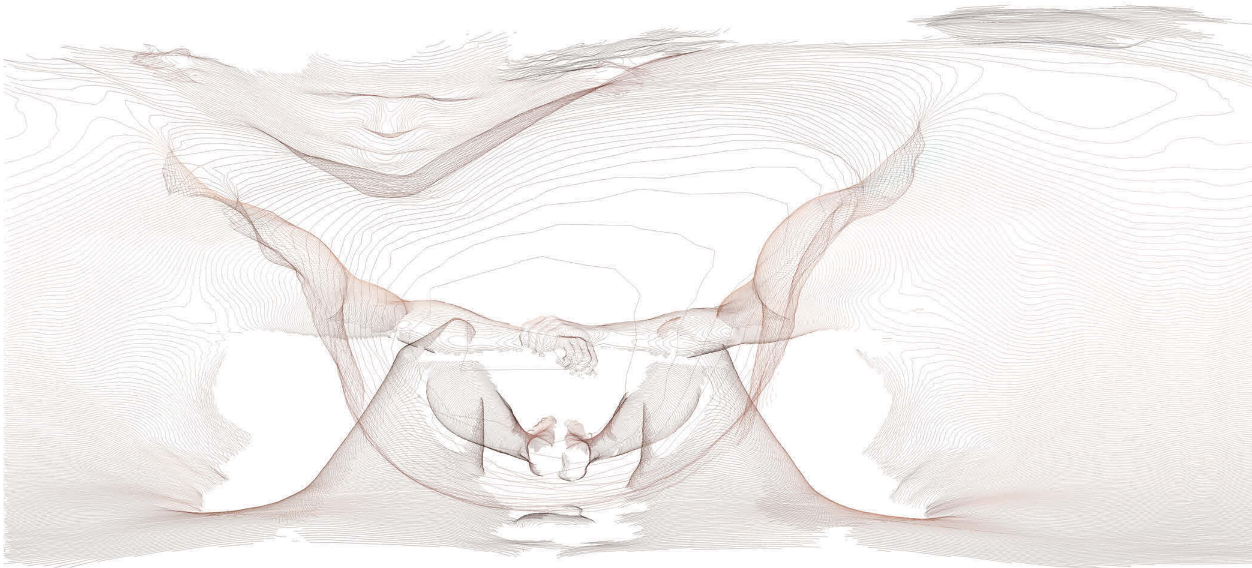


Figure 6. topo_bs1
2004
33.5″ x 16.5″
pigment print

Figure 7. thinskinned[b7]
2004
24″ x 36″
pigment print

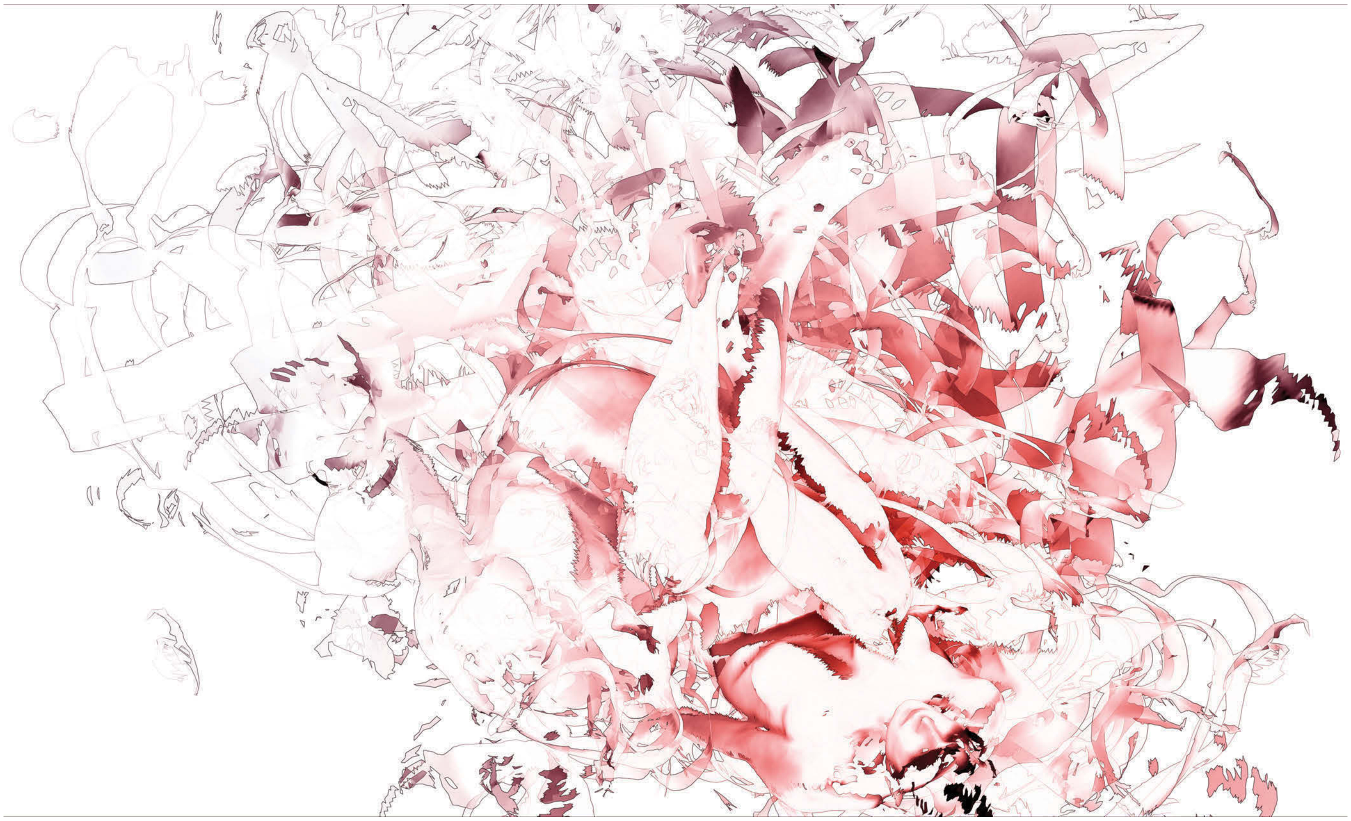


Figure 8. timeline_20seconds
2006
24" x 48"
pigment print

left any contact with the world of the map, this is not necessarily the case. "Since beginning with the map project," LoCurto and Outcault have written,

> … we've continued working with the three-dimensional scanner as a camera, having developed different software programs that allow us to deconstruct the 3d body and to produce animations by manipulating the figures and their relationship to the cameras. Points of continuing fascination for us are the ability, within the computer, to not only work with the three-dimensional figure sculpturally but also to manipulate the viewpoint of the camera. Images captured with a traditional camera are limited to a single viewpoint, fixing the photographic eye in time, whereas with three-dimensional imagery the camera essentially surrounds the subject, allowing a unique simultaneity. We continue to explore this omni directional quality of the three-dimensional photographic images, using the unlimited number of viewpoints derived from a single scan to place the viewer outside the frame of traditional lens-based perspectival vision. In *thinskinned*, instants from animations are revisited and compiled from numerous viewpoints, capturing a single moment from multiple angles.

While it is doubtless a commonplace to speak of maps, even maps of the world, as though they were views taken from a single vantage point overhead, it is in fact the case that the map's "eye" surrounds the three-dimensional earth exactly as the whole-body scanner surrounds LoCurto and Outcault. Far from being limited to a single vantage point, maps are seen literally from an infinity of vantage points, each precisely overhead every point on the map.

This astonishing characteristic of the topographic "view" is, like so many characteristics of the map, hidden from us by our familiarity, as invisible to us as the miracle of language, or air. Confrontation with the work of LoCurto and Outcault, at once so close to that of mapmakers and at the same time so completely alien, forces us to confront afresh the bizarre, distorted, multiperspectival fact of the map, and so *re*fresh our own self-image.

What more can we ask of art?

For more images, please see the LoCurto/Outcault website: http://members.bellatlantic.net/~vze3s5q6/