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Morphological complexity of languages reflects the settlement history of the Americas

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1. Introduction

Languages vary considerably in their morphological complexity, and mean complexity levels vary considerably from language family to language family, area to area, and continent to continent. The causes of this variability include the sociolinguistics of contact vs. isolation, constraints on L2 vs. L1 learning, a certain range of random variability, and the inherent conservatism of language transmission, which preserves inherited patterns by default. Due to this latter factor historical linguists assume that significant differences in complexity – especially where they characterize not single languages but whole populations of languages – take time to develop. This makes it possible to use modern distributions of complexity to infer aspects of linguistic prehistory.

Here we present a pilot study applying three different complexity measures in order to map out the distribution of morphological complexities across North, Central, and South America (for a fuller typology of complexity measures see Sinnemäki 2011:23, Karlsson et al. 2008). We then relate the variance in complexities to the geographic dimensions of altitude and longitude via Pearson correlation analyses. This is a first assessment of interesting patterns, and a first step towards more fine-grained and elaborate statistical modeling. We further discuss implications of our preliminary results for the settlement of the Americas.

2. Morphological complexity measures

2.1 Inventory complexity

The simplest measure of complexity is *inventory complexity*, a.k.a. *taxonomic complexity,* which is the total number of units in a system, for some subsystem or set of subsystems of a language. For instance, for phonology, this could be the number of phonemes, or the number of consonants, or the number of tones, etc. (For more on inventory complexity see Sinnemäki 2008, Nichols 2009.). Here we use two measures of inventory complexity: one extracted from the Autotyp database (Bickel & Nichols 2002ff.), and one from the World Atlas of Language Structures (WALS, Dryer & Haspelmath eds. 2013).

From Autotyp we surveyed six morphological variables: inflectional synthesis of the verb*, presence of plural marking on nouns, presence of dual marking on nouns, presence of numeral classifiers, presence of gender agreement, presence of auto-gender on nouns. The morphological complexity measure is then the sum of the individual values. We are here mainly interested in morphological complexity. However, we additionally surveyed four phonological variables: number of contrastive consonant series, size of vowel inventory (S/M/L), number of contrastive tones, complexity of

syllable structure*; as well as two syntactic variables: number of default alignments of A and S, number of basic word orders. (* = these variables are represented in both Autotyp and WALS). The additional variables allow us to further assess whether the morphological complexity trends also hold beyond morphology. (The whole set of variables is that used in Nichols 2009, and comparison figures in Nichols 2015.)

From WALS we surveyed 28 features exclusively relevant to morphology. These include ordinal features such as "Number of Genders" (Chapter 30A) or "Number of Cases" (Chapter 49A), which run from 0 to "5 or more", and 0 to "10 or more" respectively, and also binary features such as "The Future Tense" (Chapter 67A), which merely give "absent" or "present", i.e. 0 or 1. To make different variables comparable, we normalize values to the interval [0,1]. The overall morphological complexity score per language is then the average across the (available) features. For details on all the features used and the methods see Bentz, Ruzsics, Koplenig & Samardžić (2016).

Similar inventory complexity measures of both the Autotyp and WALS have been used before in typological studies, for instance, by Nichols (2009), Lupyan & Dale (2010), and Bentz & Winter (2013).

2.2 Opacity or non-transparency

A closer approximation to complexity as it is encountered by language learners is *opacity*, or *non-transparency*, which can be measured as the number of departures from the ideal mapping of one form ↔ one function, or one form ↔ one meaning. For instance, to mark the plural of nouns English uses two major strategies, the productive *-s* plural as in *cats* or *dogs* and the unproductive vowel change as in *foot : feet*; and a few minor strategies such as the *-en* of *oxen* and *children* or the zero marking in *sheep, deer*, and a few others. Hausa, on the other hand, has 20 distinct kinds of plural marking (Newman 2000, Caron 2013), which are mostly non-predictable and must be lexically stipulated for each noun, a much less transparent system with 20 forms for the single function of plural. Another example is gender categories and their markers. Avar (Nakh-Daghestanian: eastern Caucasus) has three genders, all semantically predictable (human males, human females, and non-human nouns) and formally regular (the markers are *w, j,* and *b* respectively). This is a perfectly transparent gender system; the only non-transparency is the presence of gender at all, since gender agreement marks no function or category other than itself and is basically unnecessary in language (Corbett 1991). In contrast, the distant sister language Tsakhur has four genders, two of them semantically predictable and two of them arbitrary, and each gender marker has two different forms used in different morphological contexts; in addition, gender marking is prefixal for some verbs and infixal for others (Dobrushina 1999). This kind of complexity measure is described in Nichols (2015).

2.3 Word entropy

The third measure used here is *word entropy,* also called *unigram entropy*. It reflects the unpredictability associated with words in language production. By trend, a language with high morphological productivity has a wide range of word forms, higher word unpredictability, and hence higher entropy. For instance, in English there is only

one possible morphological modification of the noun *tree,* namely *trees* to mark plural[1]. In German, on the other hand, the noun *Baum* can be modified to *Baume*, *Baum(e)s*, *Bäume*, *Bäumen.* As a consequence, German has a wider range of word forms and higher word entropy. Word entropy can be measured based on parallel corpora across many languages. It thus reflects word form complexity in actual language production. For more details see Bentz et al. (2015), Bentz & Alikaniotis (2016), Bentz et al. (2016), Koplenig et al. (2016).

3. Complexity and altitude

Morphological complexity has a number of interesting distributional correlations with geography. It is higher in the Americas than in the Old World (Nichols 2009, Donohue & Nichols 2011), it increases with higher latitude worldwide (Bentz 2016), it increases with altitude (Nichols 2013, 2016), and it forms a worldwide west-to-east cline in the northern high latitudes. These last two patterns are described here with a focus on the Americas.

3.1. The Caucasus as a testbed

Where mountain highlands host permanent settlements, complexity levels tend to be higher in the highlands than in the surrounding lowlands. In Daghestan (the eastern part of the Caucasus), morphological non-transparency is highest in the highlands (Nichols 2013, 2016). Figure 1 shows gender classification and gender agreement categories in Avar, Tsakhur (discussed above), and their sister languages, their locations, and their complexity levels. The important lowland contact languages – Avar, Andi and its closest sisters, Lezgi, Udi[2] – have the lowest non-transparency levels, and Tsakhur and others in the highlands have the highest. Figure 2 plots non-transparency of gender marking against altitude for the languages of Daghestan. There is a moderate correlation on the verge of significance ($r = 0.36$, $p = 0.06$): languages spoken at higher altitudes tend to be less transparent. Note that this carefully collected language sample is necessarily small ($N = 28$), which certainly impedes statistical significance.

Figure 1 about here
Figure 2 about here

In the eastern Caucasus towns and villages are strung out along the major river canyons, and in the highlands every small town or village often has its own unique language. Table 1 shows languages along the Andi Koisu and Avar Koisu for which morphological opacity has been calculated. Similar vertical chains can be traced along the right bank of the Avar Koisu and along the Samur in the south. These involve fewer languages than the plot shown in Figure 1, but the relative opacity levels and altitudes are directly comparable here, and they show the same sort of correlation, with higher opacity at higher altitudes.

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1 Potentially also the clitic *'s* to mark possession.

2 Udi is now a small enclave language, known for its exotic feature of endoclisis (Harris 2002), but in the early to mid first millennium it appears to have been an inscriptional and inter-ethnic language of some importance.

Table 1. Opacity levels of noun, pronoun, and verb inflectional paradigms in languages along the Andi Koisu (left bank) and Avar Koisu rivers in Daghestan. Languages are ordered by relative position along rivers (headwaters at the top). Branches of Nakh-Daghestanian are in parentheses.

	Andi Koisu	*Avar Koisu*	*Opacity*
		Hunzib (Tsezic)	32
Highland:	Hinuq (Tsezic)		24
	Tindi (Andic)		15
	Godoberi (Andic)		14
	Karata (Andic)		16
Lowland:	Avar (standard) (Avar)		18

Complexity levels in these examples correlate with altitude, but altitude itself is not the causal factor. Rather, it is the greater sociolinguistic isolation of highland villages that accounts for the greater complexity of their languages (Nichols 2013, 2016). These villages – difficult of access, distant from markets, with short growing seasons, and almost entirely endogamous – receive almost no immigrants and therefore almost no L2 learners, and it is intake of L2 learners that most clearly tends to decomplexify languages (Dahl 2004, McWhorter 2007, McWhorter 2016, Lupyan & Dale 2010, Trudgill 2011, Bentz & Winter 2013, Bentz, Verkerk, Kiela, Hill & Buttery 2015, Bentz & Berdicevskis 2016).

3.2 Altitude and complexity in South America

Turning to South America, morphological complexity correlates with altitude as well. Figure 3 illustrates relationships between altitude and three morphological complexity measures. The first is word entropy; the other two are inventory complexities based on Autotyp and WALS (opacity metrics for these are not available at the time of writing).

Figure 3 about here

The correlation for altitude and word entropy is moderate and significant ($r = 0.36$, $p < 0.0001$), while weaker and non-significant for inventory complexity based on Autotyp ($r = 0.19$, $p > 0.05$), and based on WALS ($r = 0.30$, $p = 0.06$). Again, the latter two run into the problem of data sparsity. While word entropy can be calculated for 162 South American languages in this sample, Autotyp and WALS only give 31 and 40 data points respectively. This certainly explains the drop in significance. Importantly, all three measures agree in their positive correlation of morphological complexity and altitude.

Figure 4 visually illustrates the altitude effect for South America. It depicts the 162 South American languages of the word entropy sample on a three dimensional topographic map. Larger dots correspond to higher word entropy, i.e. complexity. The altitude/complexity relationship is driven by languages spoken in the Andean region, which are generally morphologically complex. Languages of the Amazonian areas in the lowlands are – on average – less morphologically complex.

Figure 4 about here

Zooming into the Andean highlands, we further find that there can be subtle differences between language groups in terms of the inventory and opacity metrics. Table 2 shows succession to power and non-transparency levels in the southern Andean highlands.

Table 2. Language succession and decomplexification in the Andean *altiplano*. Overall: combination of phonological, morphological, and syntactic inventory sizes based on Autotyp; Morphological: morphological inventory size only.

Language, economy, history	*Overall*	*Morphological*
Uru-Chipaya: Chipaya. Riverine/lacustrine. Non-state language. Long indigenous.	22	12
Aymaran. Agricultural		
Jaqaru: Non-state. Long indigenous.	22	14
Aymara: Pre-Inka state language (c. 500-1000 CE)	20	12
Quechuan. Agricultural		
Central: Peruvian highlands	17	11
Peripheral: Long indigenous (Huallaga, Tarma)	18	12
Central: Coastal trade variety spreads as interethnic language (Cochabamba, Ayacucho, Cuzco)	18-19	10-11
Central: Official language of Inka empire (13th-16th centuries) (Imbabura)	16	9

The Uru-Chipaya family, well entrenched in the highlands for at least the last few millennia and probably longer, is sociolinguistically isolated and quite complex. Equally complex is Jaqaru of the Aymaran family, long indigenous in the highlands. Its sister Aymara, the pre-Inka state language, is less complex. Peripheral Quechuan languages and the coastal trade language that spread after the pre-Inka state collapse are less complex, and the central varieties descended from the Inka imperial language still less complex. (For the linguistic history of the Andes see Adelaar & Muysken 2004.) Complexity

levels among neighboring languages range from almost as high as Chipaya in the south (Mapudungun, isolate of Patagonia; Matacoan and Guaycuruan families, northwestern Argentina) to much lower in the north (Arawakan, Panoan, and Jivaroan families, all of Peru; Barbacoan family, Colombia). Overall, then, it seems that morphological complexity started out high in the Andean *altiplano* and decreased with contact and especially statehood; complexity levels were slightly lower to start with in southern neighbors and much lower to start with in the high-contact region of Peruvian upper Amazonia. In very different ways, imperial Quechua and the diverse languages of upper Amazonia are high-contact languages, with immigrants and language learners absorbed by state expansion in the highlands and traditional intermarriage and mobility in Amazonia.

4. Complexity and longitude

Figure 5 shows overall levels of inventory complexity (Autotyp-based) for 193 languages surveyed worldwide. In the high latitudes (above 40° N) there is a fairly strong correlation of complexity and longitude ($r = 0.42$, $p < 0.001$): complexity levels are low in western Europe and increase to high in eastern North America. The mid and low latitudes of the northern hemisphere show a very similar correlation ($r = 0.42$, $p < 0.01$), while for the southern continents (Africa, Australia-New Guinea-Oceania, South America) this is considerably reduced and non-significant ($r = 0.19$, $p = 0.08$). Note that this reduction and non-significance is not due to smaller sample size (N=82, compared to N=65, and N=45).

Figure 5 about here

The longitude/complexity relationship is then a mainly northern phenomenon, and it links the entire high-latitude northern hemisphere in a single typological trend. The cline obtains within Eurasia, as seems to be in line with the deep connections posited by Jäger (2015) based on lexical similarity, but continues beyond into North America. Also, we would connect differences in complexity to sociolinguistics more than to common descent.

Very similar correlations between longitude and language structure are exhibited by all other morphological phenomena allowing fine or multivariate breakdowns that we have surveyed: inflectional person (very strong correlation), causativization as preferred realization of the causative alternation, and noun-based vs. verb-based word formation (Nichols, unpublished data). For all of them, the linguistic population of the Americas generally belongs typologically with the easternmost end of the gradient (cf. Bickel & Nichols 2006). The interpretation of this distribution would appear to be that high morphological complexity has long been (as it is now) a trait of the North Pacific Rim population, from which ancestral colonizing languages entered North America, eventually to populate the entire hemisphere (see Figure 6). Subsequently, probably beginning only with the Neolithic, complexity levels were reduced in much of the Old World as complex societies and states expanded and trade languages formed, spreading languages to L2 learners. Highland languages, such as the ones surveyed here in the Andean region of South America, might have a) complexified in sociolinguistic isolation, or b) reverted to the earlier and probably default situation (Bickel & Nichols 2003) – or

both. Furthermore, in the Americas, the same processes as observed in Eurasia occur independently (at least pre-contact): statehood lowers complexity levels (in Central America and the Andes) compared to more isolated, agricultural highland languages.

Figure 6 about here

4. Conclusions

Our preliminary analyses of relationships between altitude, longitude and morphological complexity confirm the uncontroversial origin of the indigenous American languages in the North Pacific Rim population. More intriguingly, they indicate that – across the board – high morphological complexity levels (and other traits) of that population have been a) maintained in offspring populations for many millennia, and b) even enhanced through further isolation in certain areas such as the Andes. Thus, the American linguistic population is old enough that contrasts of complexity between high altitude and low altitude areas have developed, and they are observable now. The rate at which these processes evolve is currently not known. The least we can say is that since it has come to affect entire areal populations of languages (and not just the occasional individual language) it is unlikely to have happened quickly, i.e. within a few hundred years. The modern complexity levels, then, are a window into deep population movement, contact, and isolation. Establishing rates of change for simplification and complexification will help to support hypotheses about the possible earliest entries into the Americas.

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Figure 1. Topographic map of the eastern Caucasus, showing Nakh-Daghestanian languages. Black = most transparent, gray = intermediate, white = least transparent. Language labels indicate major contact languages, and Tsakhur, discussed above in text.

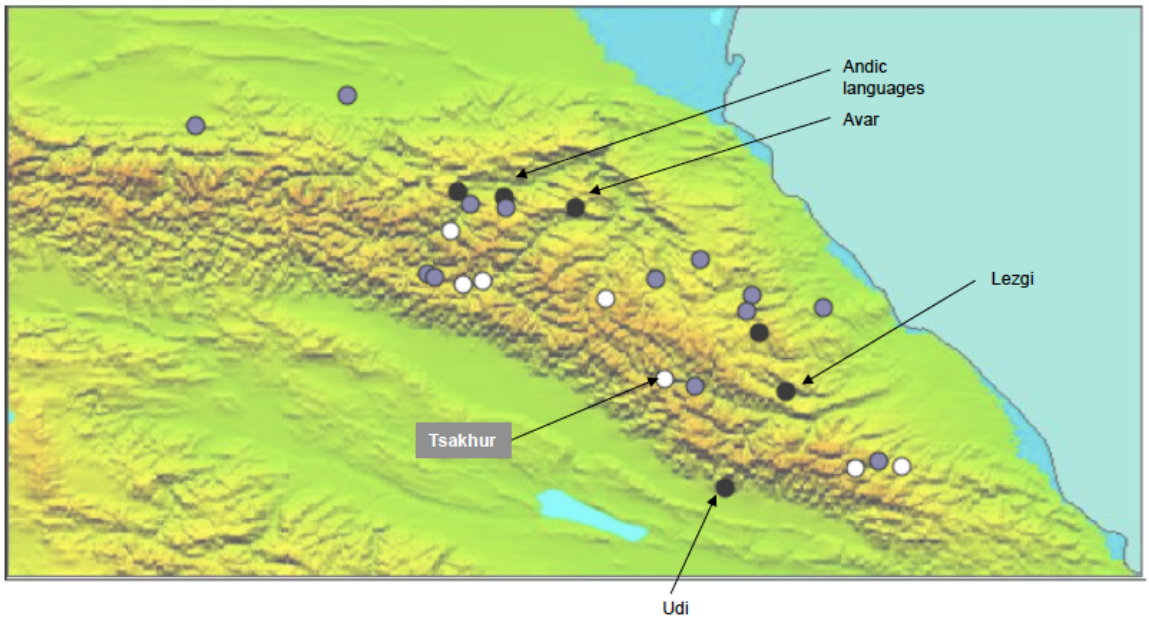


Figure 2. Non-transparency and altitude in the languages of Daghestan (eastern Caucasus). *N* = 28. Adopted and modified from Nichols (2013, 2016). The Pearson correlation is r = 0.36 (p = 0.06). Gray line indicates a linear regression model with 95% confidence band.

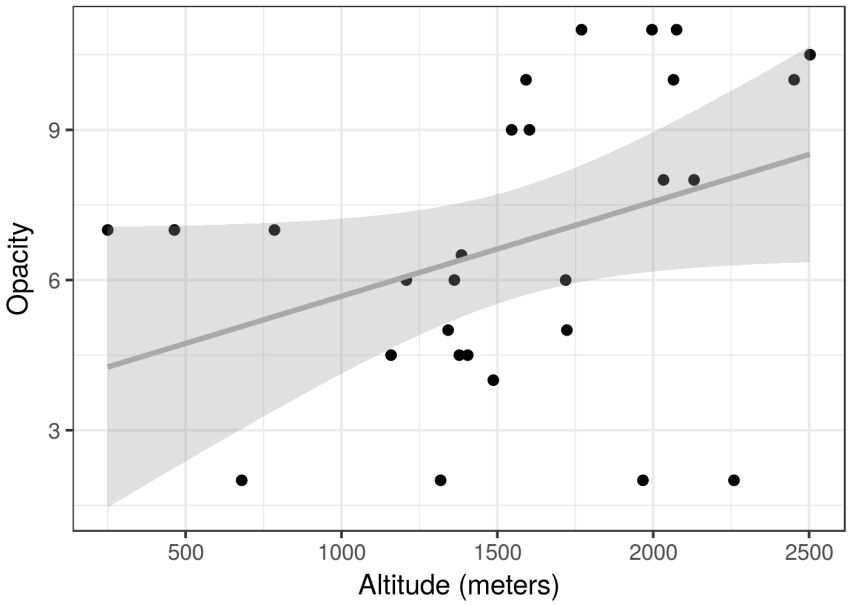


Figure 3. Correlations between altitude (x-axis) and scaled morphological complexity measures (y-axis) in South America. The three measures are word entropy for 162 languages (left panel), inventory complexity based on the Autotyp database for 31 languages (middle panel), and inventory complexity based on the World Atlas of Language Structures (WALS) for 40 languages. The Pearson correlations are from left to right: $r = 0.36$ ($p < 0.001$), $r = 0.19$ ($p > 0.05$), $r = 0.30$ ($p = 0.06$). Gray lines indicate linear regression models with 95% confidence bands.

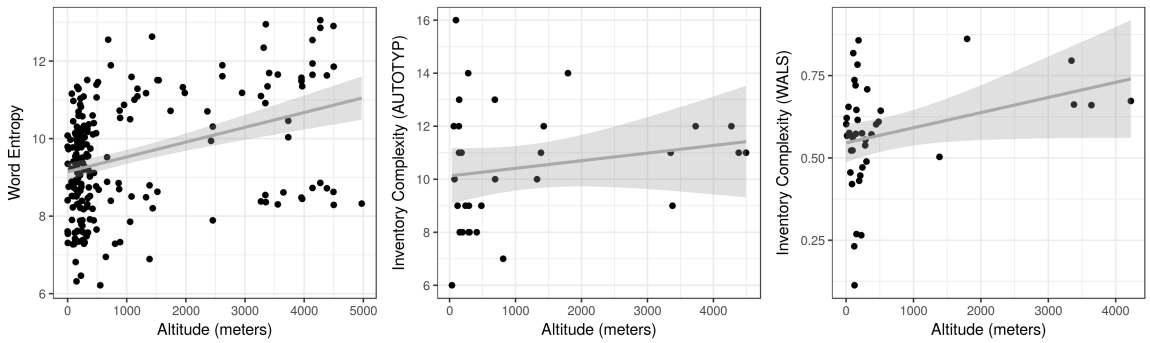


Figure 4. Topological plot of altitude and word entropy across South America. Every black dot corresponds to one of 162 languages in the word entropy sample. Larger dots correspond to higher entropy – as a proxy for higher morphological complexity.

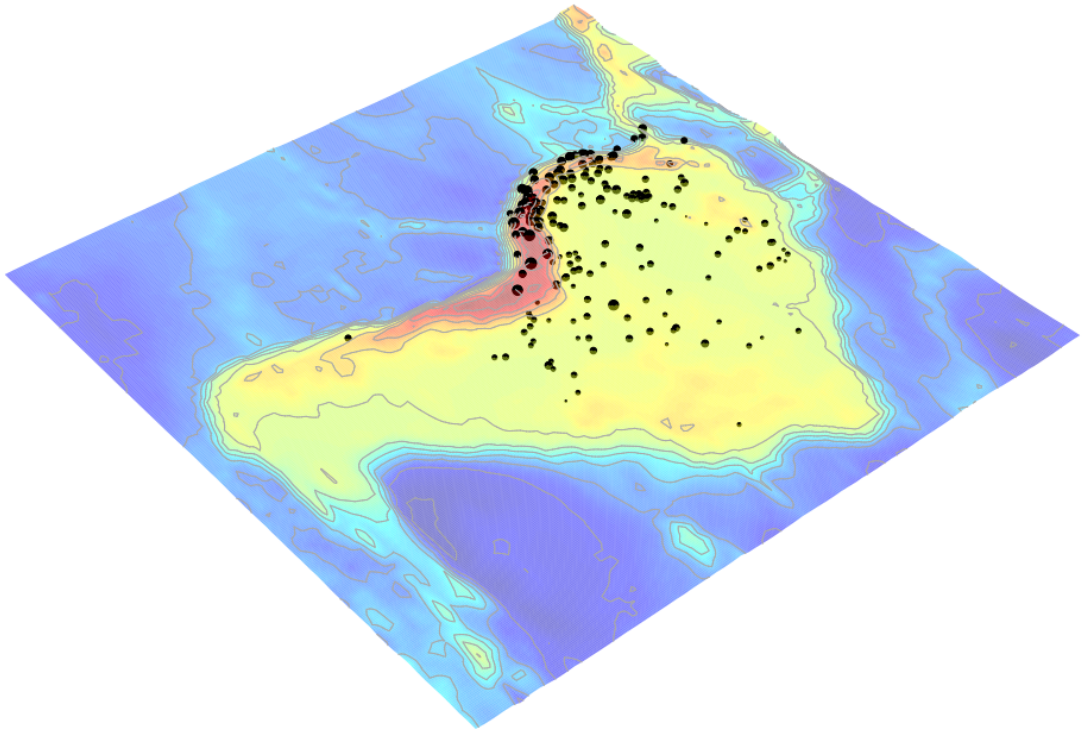
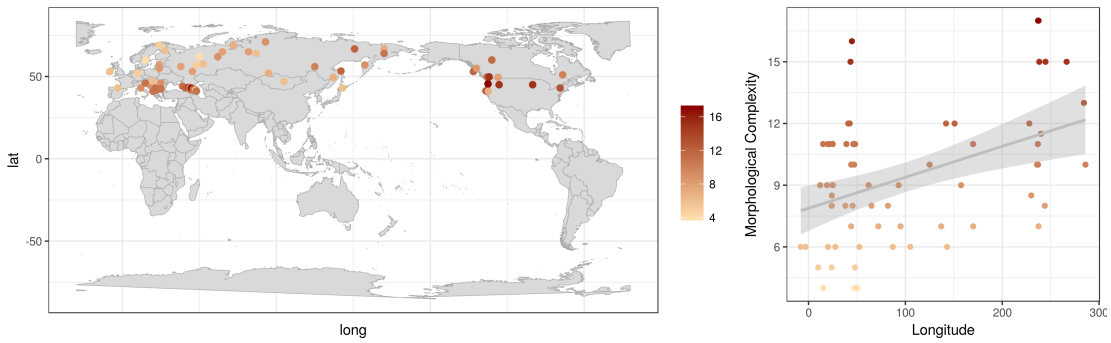
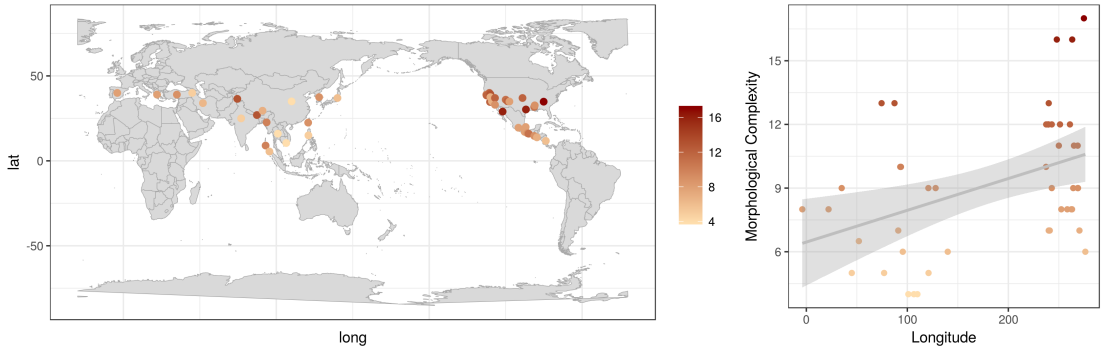


Figure 5. Morphological complexity (inventory complexity after Autotyp) plotted against longitude, for three latitudinal bands, and overall 193 languages. Longitudes run from -30 to 330. (a), 65 languages of the northern hemisphere above 40°N ($r = 0.42$, $p < 0.001$); (b), 45 languages of the northern hemisphere below 40° N ($r = 0.42$, $p < 0.01$); (c) 82 languages of the southern continents (Africa at left, Australia-New Guinea-Oceania in center, South America at right) ($r = 0.19$, $p = 0.08$). Gray lines indicate linear regression models with 95% confidence bands.

(a)



(b)



(c)

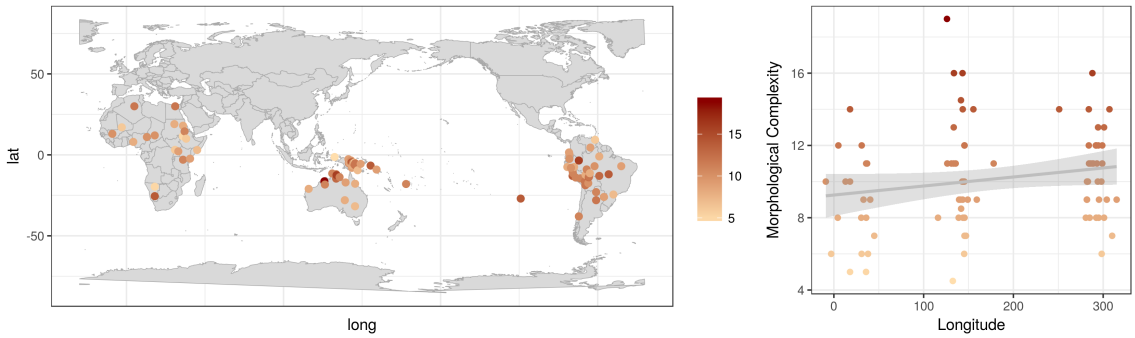


Figure 6. Long-standing trajectories of language spread from Eurasia to the Americas (and the Pacific, not discussed here). (Rootsi et al. 2007, Bickel & Nichols 2006, Nichols 2000)