Title: Areal patterns in the vowel systems of the Macro-Sudan Belt

Abstract: This paper investigates the areal distribution of vowel systems in the Macro-Sudan Belt, an area of Western and Central Africa proposed in recent areal work (Güldemann 2008, Clements & Rialland 2008). We report on a survey of 681 language varieties with entries coded for two phonological features: advanced tongue root (ATR) harmony and the presence of interior vowels (i.e. non-peripheral vowels [ɨ ɯ ɜ ə ʌ …]). Our results show that the presence of ATR harmony in the Macro-Sudan Belt is limited to three geographically unconnected zones: an Atlantic ATR zone, a West African ATR zone, and an East African ATR zone. Between the West and East African ATR Zones is a genetically heterogeneous region where ATR harmony is systematically absent which we term the Central African ATR-deficient zone. Our results show that in this same Central African zone, phonemic and allophonic interior vowels are disproportionately prevalent. Based on this distribution, we highlight two issues. First, ATR and interiority have an antagonistic relationship and do not commonly co-occur within vowel systems, supported through statistical tests. Second, our survey supports the existence of the Macro-Sudan Belt, but due to ATR being systematically absent in Central Africa, this weakens the proposal that this area represents the 'hotbed' of the Macro-Sudan Belt (Güldemann 2008:167).

Keywords*:* phonology, vowel systems, vowel harmony, ATR, macro-areas, areal typology, Africa

1 Introduction

There has been a recent resurgence in Africanist linguistics towards areal explanations of shared linguistic features, rather than genetic explanations assuming common descent from a mother language (i.e. Greenberg's 1963 African stocks Niger-Congo, Nilo-Saharan, Afroasiatic, and Khoisan). One prominent areal proposal in Africa is the Macro-Sudan Belt Hypothesis (Clements & Rialland 2008, Güldemann 2008), a macro-area south of the Sahara desert and north of the Congo rainforest stretching from Senegal in the west to South Sudan in the east, largely coextensive with Greenberg's (1959, 1983) 'African core area' (Güldemann 2011:111-112). This macro-area is defined based on the disproportionate presence of features not found to its north, east, and south, including phonological features (ATR harmony, three or more tone heights, implosives, labial-velar stops) and grammatical features ('lax' question markers, logophoricity, word orders S-AUX-O-V-X and V-O-Neg).

Macro-areas are like traditional 'sprachbunds' in being supported by the common linguistic features across languages which cannot be attributed to genetic inheritance. In other ways, however, macro-areas are distinct. Muysken (2008:5) notes that unlike smaller linguistic areas, macro-areas have no clear contact scenarios, while Güldemann (2008) stresses specifically for the Macro-Sudan Belt that it could not have arisen under a single historical event. Macro-areas should rather be defined as a region over which linguistic features spread more easily compared to spreading into other regions, and therefore does *not* entail that all features are equally distributed or that even a majority of languages possess the linguistic features. Macro-areas therefore represent the most abstract type of linguistic area, and are consequently more difficult to evaluate compared to traditional sprachbunds.

Despite these challenges, the central goal of this paper is to examine the Macro-Sudan Belt and further refine some of the criteria which have been used to justify its existence. We do this by examining the distribution of vowel systems within it. One criterion said to define the Macro-Sudan Belt is the existence of Advanced Tongue Root (ATR) Harmony, in which vowels within a specific phonological domain - usually the phonological stem or word – obligatorily agree for a

[+ATR] or [-ATR] specification. We examine vowel systems in the Macro-Sudan Belt by constructing a largescale database called the Areal Linguistic Features of Africa (ALFA). ALFA consists of information on vowel systems from 681 language varieties from every major subgroup within the Macro-Sudan Belt, forming 47 sub-groupings in total, and is the largest of its kind. An advantage of ALFA is that we encoded not only phonemes but also allophonic variants and epenthetic vowels, which allows us to assess commonalities in vowel patterning at both a phonological and sub-phonological level. Allophony is typically overlooked in existing phonological databases, which only encode phonemic contrasts.

Our survey yields a number of important results to further refining our understanding of this Belt. First, we show that there are five phonological 'zones' within the Belt, within which languages converge on a specific vocalic profile. This is shown below in Figure 1.

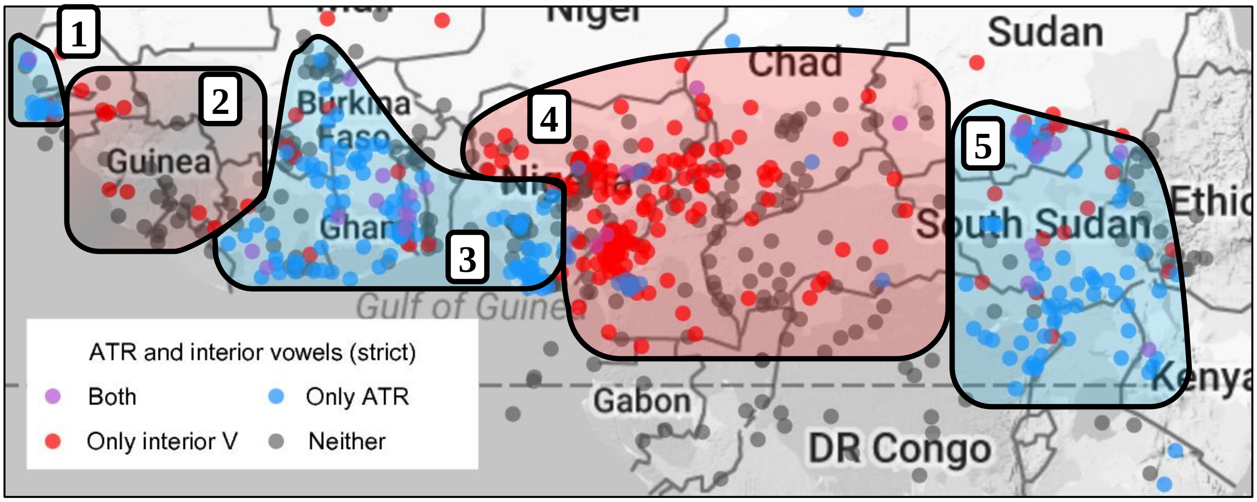

Figure 1: Five areal zones defined by vocalic systems in the Macro-Sudan Belt: [1] Atlantic ATR zone, [2] Guinean ATR-deficient zone, [3] West African ATR zone, [4] Central African ATR-deficient zone (includes Central African interior vowel zone), [5] East African ATR zone

Zone 1 is the Atlantic ATR zone around present-day Senegal. This ATR zone has what we refer to as complete ATR, in which there is cross-height harmony between [+ATR] /i u/ and /e o/ and between [-ATR] /ɪ ʊ/ and /ɛ ɔ/. Zone 2 is the Guinean ATR-deficient zone which systematically lacks complete ATR and has either No ATR or incomplete ATR. incomplete ATR systems are largely systems with trace ATR cross-height harmony or only mid harmony in which /e o/ do not co-occur with /ɛ ɔ/. Zone 3, the West African ATR zone, and Zone 5, the East African ATR zone, are large areas within which complete ATR is widespread. Finally, Zone 4 is the Central African ATR-deficient zone, within which complete ATR is systematically absent.

Second, we make the novel claim that in the Central African ATR-deficient zone, vowel systems disproportionately contain interior vowels (e.g. y ɨ ʉ ɯ ə, etc.), seen in Figure 1 by the large number of red dots within this Zone 4. We refer to this as the Central African interior vowel zone, and show that ATR systems within the Macro-Sudan Belt commonly lack interior vowels. Within Central Africa, we can identify a Nigerian ATR boundary separating Zones 3 and 4, a Sudanese ATR boundary separating 4 and 5, and a Central African interiority boundary within Zone 4 separating the western and northern quadrants from the southeastern quadrant. One of the ramifications of our interiority survey is explicitly linking those Chadic languages in Chad and Northern Nigeria/Cameroon to the Niger-Congo phylum Bantoid and Delta-Cross families towards the south, adding to the growing body of data showing that Central Africa is a linguistic area in its own right.

We see three main contributions of this work. First, we provide the most thorough mapping of the distribution of ATR systems and interior vowels in the MSB to date, based on our extensive database. Second, this paper demonstrates that ATR and interiority are not independent from one another, regardless of whether ATR and interiority are defined strictly or liberally. However, when we eliminate all complete ATR and incomplete ATR systems from our dataset and assess the relationship between interiority and the presence of two or more mid heights, we do not find evidence for a similar dependence. As a whole, we interpret these results as the following: the existence of harmony involving the acoustic dimension of F1 (including both ATR harmony and incomplete ATR harmony, such as mid harmony) is antagonistic to interior vowel phones defined primarily along F2, and vice versa.

Third, as expected our survey of ATR supports the existence of the Macro-Sudan Belt which had smaller samples of languages. However, because ATR is systematically absent in Central Africa, this complicates the notion that it is the 'hotbed' of the Macro-Sudan Belt (Güldemann 2008:167, 2010), and possibly even weakens the concept of 'hotbeds' within macro-areas altogether. This more conservative position views macro-areas as a continuum made of several partially overlapping phonological areas, with no real center/hotbed. We ultimately see our efforts as emphasizing the importance of a dialogical relation between the micro- and macro-perspectives.

2 Areality in Africa

2.1 Background

Research on areality in Africa has a long and rich history, but it has consistently been overshadowed by the desire for large-scale genetic classifications. Africanist linguists are best thought of as 'lumpers' rather than 'splitters' (Campbell 2003:34-35 for terminology), and have long explicitly or implicitly adopted pre-existing genetic classifications such as Greenberg's (1963) phyla Afroasiatic, Niger-Congo, Nilo-Saharan, and until recently 'Khoisan'. Of Greenberg's four phyla, Afroasiatic is the least controversial, while Khoisan is no longer recognized as a single genealogical unit (see Güldemann 2014 and references therein). Niger-Congo and Nilo-Saharan each have a core class of families for which genetic relation is apparent (e.g. Bantoid in Niger-Congo, Nilotic in Nilo-Saharan, a.o.) but also contain several large families which are considered to be related to the core at a considerable genetic distance, if at all. Within Niger-Congo, controversial families include Ijoid, Mande, Atlantic[1], and Kordofanian (Williamson 1989: 1-45). Within Nilo-Saharan, 'outlier' groups (e.g. Saharan) and 'satellite' groups (e.g. Central Sudanic) in Bender's (2000) classification are likewise putative at best (cf. Güldemann to appear: 138-146, 150-216). These hypotheses have been highly valuable in generating decades of comparative work and sharpening the evidence for families within these phyla as well as grouping scholars into communities of interest, but when adopted without scrutiny result in the assumption that linguistic similarity in Africa is due to vertical genetic inheritance rather than horizontal contact-induced transmission.

Studying African linguistic patterns areally has a rich albeit less storied history. Early statements on areality in Africa include Greenberg (1959), which identified a number of phonological and morphosyntactic features which broadly characterize African languages (pp. 22-23) while tentatively remarking on the existence of sub-areas of convergence (p. 24). Following up on this work, Greenberg (1983) systematically mapped the geographic extent of

[1] Atlantic and even the subgroups within Atlantic are themselves controversial; see Merrill (2018).

four Africa-specific traits, namely labial-velar stops, labiodental flaps, ‘surpass’ comparatives, and polysemy of a term for ‘meat’/‘animal’. Greenberg’s (1983) study built on large-scale African typological work by Welmers (1973) and Gregersen (1977), supporting a notion that there is a nuclear area in Africa in which areal characteristics are most intense, centered around present day Eastern Nigeria/Cameroon/Central African Republic (an area which we will return to below).

Other areal-typological work in Africa sought to identify different types of African languages based strictly on shared grammatical traits. Heine’s (1976) study of word order types develops an African language typology divided into 4 groups (A: consistent SVO; B: SVO with head-final genitive construction, SOV with postverbal obliques; C: VSO; and D: SOV), themselves divided into a number of sub-groups with skewed geographical distributions (Heine & Nurse 2008). Other early areal-typological Africanist works include Larochette (1959), Thomas et al. (1973), Meeussen (1975), Houis (1980), and Gilman (1986) (see also Güldemann 2008:170-174 for overview discussion). These works have provided specific criteria to establish particular areas, and have identified important concentrations of linguistic features and their isoglosses.

The recent resurgence of areal-typological research in this century has furthered our knowledge. These include areal-typological volumes on West and Central Africa (Zima 2000, 2009; Comrie & Wolff 2004; Caron & Zima 2006) as well as pan-African edited volumes (Sauzet and Zribi-Hertz 2003; Voeltz 2005; Heine & Nurse 2008; Hieda et al. 2011). More specialized work has also studied the distributions of single linguistic traits over large areas, both morphosyntactic (Cyffer et al. 2009) and phonological features (Clements & Rialland 2008).

When taken all together, a number of linguistic areas of various sizes have been proposed which function as testable hypotheses. Small linguistic areas can be understood as traditional sprachbunds. In contrast, larger linguistic areas are macro-areas, which can be understood as large regions where numerous feature distributions overlap, though not necessarily uniformly. Based on phonological criteria, Clements & Rialland (2008) divide the continent into six macro-areas largely horizontal bands stretching east-west (Figure 2). In independent work, Güldemann (2008, 2010) proposes a similar division of the continent into the five macro-areas defined on the basis of both shared phonological and morphosyntactic features (Figure 3). Two of these areas — Macro-areas I ‘Saharan Spread Zone’ (Arabic, Berber) and IV ‘Bantu Spread Zone’ in Figure 4 — are genealogically homogeneous, and are thus best characterized as spread zones in Nichols’ (1992) terminology. Macro-areas II ‘Chad-Ethiopia’, III ‘Macro-Sudan Belt’, and V ‘Kalahari basin’, on the other hand, are genealogically diverse and constitute large contact areas.

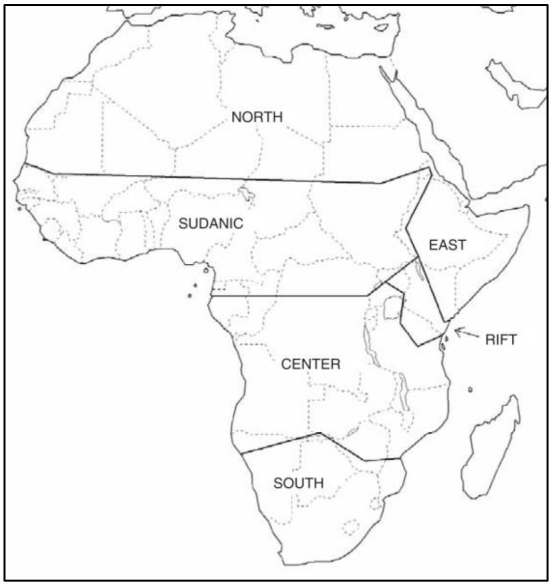

Figure 2: Macro-areas of Africa
(Clements & Rialland 2008:37)

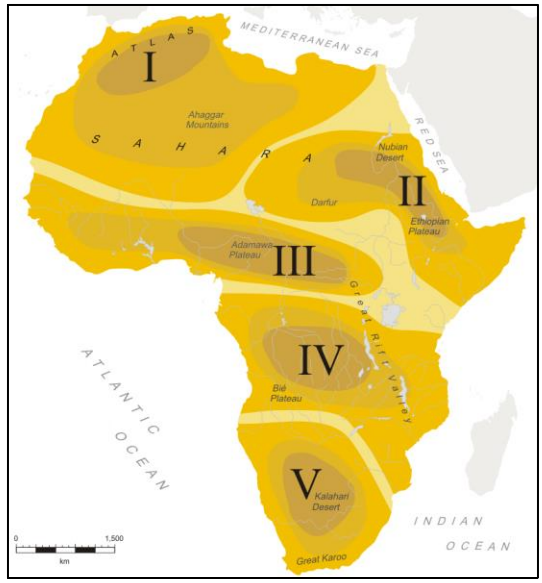

Figure 3: Macro-areas of Africa
(Güldemann 2011:110)

These maps illustrate that Clements & Rialland's 'Sudanic Belt' and Güldemann's (2008) 'Macro-Sudan Belt' are largely coextensive, and converge on an area encompassing most of Western and Central Sub-Saharan Africa (as well as a substantial part of the Eastern Sahel for Clements and Rialland, but not for Güldemann). It is defined as having advanced tongue root harmony, labial-velar consonants, labial flaps, implosives, three or more tone heights, contrastive nasal vowels, 'lax' question markers, logophoricity, and word orders S-AUX-O-V-X and V-O-Neg. Crucially, these linguistic areas are defined without reference to genetic classification, and uncontroversially involve unrelated languages, e.g. the Macro-Sudan Belt contains languages from phyla Niger-Congo, Nilo-Saharan, and Afroasiatic (as well as several isolates).

Moreover, Güldemann (2008) goes further than Clements & Rialland in that he does not only delineate his Macro-Sudan Belt, but also describes its internal structure. Indeed, we can see in Figure 4 that the Macro-Sudan Belt is split into three concentric ovoid shapes distinguishing the core and peripheral areas, with a 'hotbed' core in the center of the macro-area (Güldemann 2008:168), in dark brown in Figure 3. Güldemann's diagrams are of course abstractions, and thus allow us to further inquire about the internal diversity within the Macro-Sudan Belt and whether the distribution of vowel systems mirrors this core/periphery structure. We turn to these efforts presently.

2.2 Creating a database of vowel systems in Africa

As stated, this paper examines the distribution of two areal phonological features of the Macro-Sudan Belt: advanced tongue root (ATR) harmony, and the presence of interior vowels. To this end, we have constructed a database of vowel systems in Africa, part of a larger project at the University of XXXX called *Areal Linguistic Features of Africa* (ALFA). Our database contains a total of 681 language varieties, and we have sought to attain complete coverage of all language varieties in the Macro-Sudan Belt and its surroundings, limited only by access and reliability of relevant phonological descriptions. We include only those languages for which we had sufficient information to value all typological variables pertinent to ATR harmony and interiority. For some languages, only wordlists were available, and we include them if we surmise they are of sufficient quality. We restricted our search to primary sources, and did not consult existing databases, e.g. Ruhlen (1975), Crothers (1978), UPSID (Maddieson 1984), *Alphabets des* *langues africaines* (Hartell 1993), the World Phonotactics Database (Donohue et al. 2013), PHOIBLE (Moran et al. 2014), a.o.

Our survey included languages from all major families in the three major phyla of the Macro-Sudan Belt. Because we sought complete coverage of this area to generate more precise isoglosses, we did not balance our sample for genetic family. For example, we surveyed 69 Bantu languages but 5 South Atlantic languages. The total number from each language grouping is below in Table 1.

Family	**n**	**Family**	**n**	**Family**	**n**	**Family**	**n**
Bantu	69	Other Kwa	17	East Chadic	10	Songhai	7
Central Sudanic	40	Platoid	17	Ijoid	10	Defoid	6
Atlantic	31	West Mande	17	Jukunoid	10	Idomoid	6
Other NS	29	South Gur	16	Omotic	9	Creole	6
Adamawa	26	Biu-Mandara	15	Dogon	9	Other NC	5
Potou-Tano	26	Kainji	15	Gbe	9	Nupoid	5
Nilotic	25	East Mande	14	Surmic	9	South Atlantic	5
Central Gur	23	Gbaya	13	North Bantoid	8	Maban	5
Edoid	22	Other Bantoid	13	Igboid	7	East Kru	4
Grassfields	21	NC-Kordofanian	12	Other Gur	7	Saharan	4
Ubangi	21	Other AA	12	Senoufo	7	Other	3
West Chadic	18	Delta-Cross	11	West Kru	7		

Table 1: Languages surveyed from each Greenbergian stocks within Macro-Sudan Belt (*n*=681)
Niger-Congo (NC - *n*=487), Nilo-Saharan (NS - *n*=119), Afroasiatic (AA - *n*=66), Other (n=9)

The map in Figure 4 shows the locations of language varieties contained in the current survey, split up by Greenbergian stock. Maps throughout this paper were created using the ggmap package in R (Kahle & Wickham 2013).

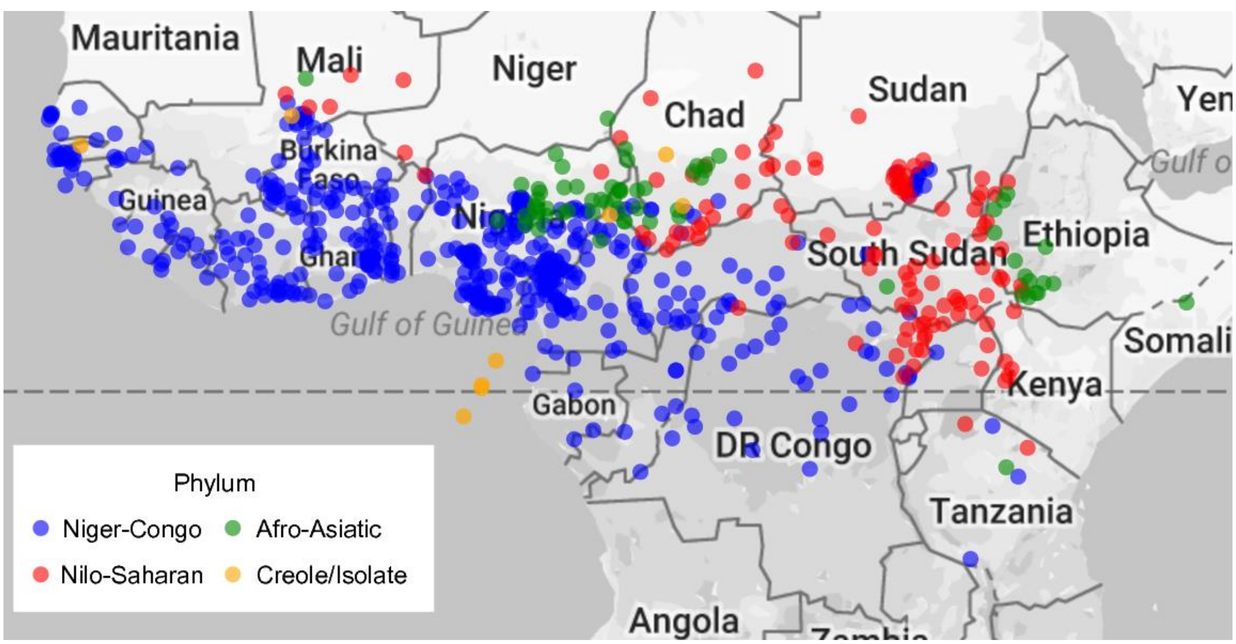

Figure 4: Map of language varieties in the ALFA database (*n* = 681)

The vowel inventory of a language is encoded in ALFA as a list of vowel qualities with associated attributes. For each vowel quality present in a language, we encoded on distributional grounds whether it must be analyzed as phonemic or has a clear allophonic relationship with some other vowel quality. For example, in the vowel inventory of Eton (Bantu A: Cameroon – van de Velde 2008), the vowel qualities [ɛ] and [ɜ] are encoded as allophones of the phoneme /ɛ/, reflecting the original analysis. Additionally, we encoded whether vowel qualities exhibit contrastive or non-contrastive modifications such as length, nasality, or non-modal phonation, whether they are epenthetic, whether they are derived from any other vowels through reduction, and whether the vowel quality is marginal in the language (e.g. found in only a handful of morphemes, only in non-nativized loanwords, or only in ideophones, etc.). By exhaustively encoding both phonemic and allophonic information on vowel qualities, we were able to examine areal distributions at different levels of linguistic representation.

Additional encoding aims to capture aspects of the operation of vowel harmony processes. To reflect the ATR harmony processes in a given language, we encoded on the basis of our own analysis one of several values for ATR system type (see the next section below), presence of [+ATR] dominance, ATR pairings, and neutral vowels. We also indicated the presence of more general height, front-back, and rounding harmony processes, and the presence of co-occurrence restrictions between two heights of mid vowels if present. A public copy of this database is provided in tabular format within our supplemental materials, as well as the citations of the primary sources which were used to construct it.

3 ATR harmony

3.1 ATR types

Other than tone, advanced tongue root (ATR) contrasts and ATR harmony are perhaps the most robustly described and analyzed features of African phonology, with an extensive body of research into its typological and phonological properties (Stewart 1967, 1971; Hall et al. 1974; Williamson 1983; Blench 1995:89-91; Baković 2000; Dimmendaal 2001; Casali 2003, 2008, 2016; Güldemann 2008; Clements & Rialland 2008, a.o.) and phonetic characterization (Starwalt 2008, Casali 2008). In ATR systems, vowels are split into two mutually exclusive groups within a relevant phonological domain (e.g. a phonological word). In the [+ATR] group, a vowel canonically shows advancement of the tongue root, which widens the pharyngeal cavity, whereas [-ATR] vowels (also called [RTR] or retracted tongue root vowels) do not. Acoustically, [+ATR] vowels tend to have a lower first formant frequency (F1) than their [-ATR] counterparts (Starwalt 2008:*vii*). As F1 is also the primary cue to contrasts in tongue height, [+ATR] vowels are often transcribed with a phone corresponding to a higher tongue body position compared to its [-ATR] counterpart, e.g. [+ATR] [e] vs. [-ATR] [ɛ]. Casali (2008) notes that ATR may be 'better defined in terms of pharyngeal cavity expansion than tongue root advancement alone', and that [ATR] contrasts may additionally be cued through voice quality, with [+ATR] vowels often described as having a 'breathy', 'deep', 'muffled', or 'hollow' quality and [-ATR] vowels as 'bright', 'choked', 'brassy', or 'creaky' quality. For the purposes of our survey, we abstract away from the phonetic implementation of ATR and concentrate on phonological behavior.

Degema [deg] (Edoid: Nigeria, Kari 2007) is an example of a vowel system with a full set of ATR contrasts, exemplified below. [+ATR] contrasts are transcribed with a /◌̘/ diacritic and [-ATR] contrasts with a /◌̙/ diacritic. Alternatively, [+ATR] is transcribed with a higher value on the IPA chart, and [-ATR] with a lower value, e.g. /i/ vs. /ɪ/ in parentheses in (1).

1. Degema ATR contrasts

[+ATR]	[-ATR]
/i̜ e̜ a̜ o̜ u̜/ (~ /i e ɜ o u/)	/i̞ e̞ a̞ o̞ u̞/ ~ (/ɪ ɛ a ɔ ʊ/)

ATR systems are said to display harmony when one set of vowels is restricted to co-occurring only with members of their same set. Typically, there are both co-occurrence restrictions within roots (static patterns) and restrictions across morphemes within the relevant phonological domain resulting in allomorphy (dynamic patterns). In (2) below, a. shows that [+ATR] and [-ATR] vowels do not co-occur within the same root. Similarly, b. shows that the causative suffix harmonizes to the ATR value of the stem resulting in allomorphy and maintaining word-level harmony. Note that in Degema orthography only the first [-ATR] vowel of the word is indicated with a dot below the vowel symbol, but all subsequent vowels in the word are [-ATR].

2. ATR harmony in Degema

a. Static: Vowel co-occurrence constraints in roots

[+ATR]	vune	/βune/	'disembowel'	(*vunɛ)
[-ATR]	mụre	/mʊrɛ/	'light (a fire)'	(*mʊre)

b. Dynamic: Vowel co-occurrence constraints across morphemes (allomorphy)

[+ATR]	duw	/duw/	'be soft'	duw-ese	[duwese]	'cause to be soft'
[-ATR]	sịn	/sɪn/	'climb	sịn-ese	[sɪnɛsɛ]	'cause to climb'

We encode three types of ATR harmony system for the 681 languages in ALFA. Nearly half of the database (*n*=322) exhibit no ATR harmony processes. We label the remaining languages as either complete ATR systems (*n*=217) or incomplete ATR systems (*n*=142). The use of the term 'incomplete' for ATR comes from (Ladefoged 1968:37), and may also be called 'reduced' ATR harmony (Williamson 1973, 1983; van der Hulst & van de Weijer 1995:512).

Complete ATR systems (*n*=217) have ATR pairs in both the high and mid heights and demonstrate cross-height harmony (Stewart 1971:198), i.e. [+ATR] high vowels can only occur with [+ATR] mid vowels, and [-ATR] high vowels only occur with [-ATR] mid vowels. No sequences of vowels such as *[u…ɛ] or *[ɔ…i] occur. Note that the presence or absence of [+ATR] low vowel qualities, such as /ə/, /ɜ/, or /a̜/, plays no role in this classification.

We specify three subtypes of complete ATR systems, shown in Table 2. Five-height (5Ht) systems are the most numerous type of complete ATR system, and include languages with contrastive high and mid [ATR] phonemic counterparts. The Degema examples from (1-2) above exemplify this type, shown in a. in the table below.

a.	5Ht (*n*=195)			b.	5Ht[M] (*n*=19)			c.	5Ht[H] (*n*=3)		
	i		u		i		u		i		u
	ɪ		ʊ		ɪ		ʊ		[ɪ]		[ʊ]
	e	(ə)	o		[e]	(ə)	[o]		e	(ə)	o
	ɛ		ɔ		ɛ		ɔ		ɛ		ɔ
		a				a				a	
Ex.	Degema				Kakwa				Ijesa Yoruba		

Table 2: Complete ATR types (*n*=217)

Two additional types constitute systems which demonstrate cross-height harmony, but where one set of [ATR] values are allophonic variants of its counterpart type at the same height, and are therefore not contrastive. Example b. is an example of a 5Ht[M] complete system, in which [+ATR] /i u/ contrast with [-ATR] /ɪ ʊ/, but [e o] and /ɛ ɔ/ are allophones of /ɛ ɔ/.[2] For example, the 5Ht[M] language Kakwa [keo] (Nilotic: South Sudan - Onziga & Gilley 2012) has an ATR harmony system with the phonemes /i ɪ ɛ a ɔ ʊ u/, but no phonemes */e o/. A sample of words with identical vowels is provided in Table 3. However, when /ɛ ɔ/ appear in the context of [+ATR] /i u/, the former surface as [+ATR] variants [e o] respectively, e.g. /pírɛ́/ 'fatten' [píré] and /ɔ́pú/ 'corpse' [ópú].

/i/	/ɪ/	*/e/	/ɛ/	/a/	/ɔ/	*/o/	/ʊ/	/u/
pirî	wírî	-	lɛ́mɛ	máta	mɔ́kɔ	-	mʊ́gʊ́	pút̪ú
'place'	'song'	-	'grass type'	'chief'	'leg'	-	'body'	'dust'

Table 3: Example of 5Ht[M] complete ATR system in Kakwa

Analogously, type c. in Table 2 illustrates the 5Ht[H] subtype of complete ATR system, where /e ɛ o ɔ/ are contrastive phonemes, but [-ATR] [ɪ ʊ] are strictly allophones of [+ATR] /i u/ in the context of [-ATR] /ɛ ɔ/. These systems are common in Yoruba [yor] dialects such as Akure, Ijesa, Ekiti, and Ifaki (Capo 1985; Casali 2003:325; Przezdziecki 2005).

One complex subtype of complete ATR system involves two sets of vowels which are phonetically identical but differ with respect to their behavior in ATR harmony. One example is Okpe [oke] (SW Edoid, Benue-Congo: Nigeria – Hoffmann 1973, Omamor 1988, Elugbe 1989:70, Archangeli & Pulleyblank 1994:250-256). For some speakers, one can analyze nine phonemes /i e_1 e_2 ɛ a ɔ o_2 o_1 u/ where both /e_1 e_2/ and /o_1 o_2/ map to the same phonetic vowel qualities [e] and [o], respectively, but are distinguished based on phonological behavior: /e_1 o_1/ trigger [-ATR] allomorphs of functional morphemes and act phonologically as high vowels (i.e. /ɪ ʊ/), whereas /e_2 o_2/ trigger [+ATR] allomorphs. Several such systems are attested in southern Nigeria, including the Edoid language Urhobo [urh] (Ojaide & Aziza 2007) and the Delta-Cross language Lokaa [yaz] (Akinlabi & Liberman 2006). For our purposes, we classify such systems as 5Ht complete ATR systems.

Finally with respect to complete ATR, note that vowel systems which have a full set of 9 to 10 contrastive vowels /i ɪ e ɛ (ə) a o ɔ u ʊ/ largely constitute ATR systems in the Macro-Sudan Belt, but not all of them. For example in Shwai [shw] (NC Kordofanian: Sudan - Guest *et al*. 1998), vowels /i ɪ/ are contrastive but may co-occur, e.g. compare /viði/ 'cut hair' vs. /ðixɪ/ 'thorn', with similar patterns for mid vowels (e.g. /oɽɛl/ 'piece of stone'). Shwai is therefore classified as having no ATR harmony.

The second type of ATR harmony system we distinguish is incomplete ATR systems. In this type, vowel restrictions exist which resemble ATR but crucially do not demonstrate dynamic cross-height harmony. Most incomplete ATR systems can be described as 'mid harmony' languages (122/142 incomplete ATR systems). Mid harmony languages have a typical vowel inventory /i e ɛ (ə) a ɔ o u/, lacking the [-ATR] high counterpart of /i u/ both as contrastive phonemes (*/ɪ ʊ/) and as allophonic variants (*[ɪ ʊ]). Mid harmony languages show co-occurrence restrictions at the mid height whereby mid-close vowels /e o/ do not co-occur with mid-open /ɛ ɔ/ and vice versa, i.e. *[e…ɛ] and *[ɔ…o] in grey in Table 4 below.

[2] Note that the 5Ht[M] system corresponds to Casali's (2003:309) 4Ht(H) system.

	Sequences			Sequences	
✓	i…i	i...u	✓	u...i	u...u
✓	i…e	i...o	✓	u...e	u...o
✓	i…ɛ	i...ɔ	✓	u...ɛ	u...ɔ
✓	e...i	e...u	✓	o...i	o...u
✓	e...e	e...o	✓	o...e	o...o
*	e...ɛ	e...ɔ	*	o...ɛ	o...ɔ
✓	ɛ...i	ɛ...u	✓	ɔ...i	ɔ...u
*	ɛ...e	ɛ...o	*	ɔ...e	ɔ...o
✓	ɛ...ɛ	ɛ...ɔ	✓	ɔ...ɛ	ɔ...ɔ

Table 4: Mid height co-occurrence restrictions in mid harmony incomplete ATR systems

Mid harmony systems may or may not show dynamic restrictions in the mid heights. Productive dynamic patterns are common in Dogon languages, e.g. in Tommo So [dto] (McPherson & Hayes 2016). High vowels /i u/ are not triggers or targets of harmony processes, but mid vowels /e ɛ o ɔ/ are. Compare the form of the reversive suffix /-ilɛ/ in /dɛ̀bɛ́-ílɛ́/ [dɛ̀bílɛ́] 'get unstuck' to /némbé-ílɛ́/ [némbílé] 'cut off a branch'. In contrast, Gbeya [gbp] (Gbaya: Central African Republic) has only a static mid harmony restriction in roots. Samarin (1966:50) notes that Gbeya suffixes such as demonstrative /-ɛ/ do not alternate in the context of /e o/, e.g. [ạ a yór-ɛ] 'there he stands nearby'. In our survey, we encode both types as mid harmony but note in our database if mid co-occurrence patterns are static or dynamic.

As Casali's work points out, there are several notable differences between complete ATR systems and incomplete mid harmony systems with respect to phonological activity which we do not assess in this current paper. Complete ATR systems are canonically [+ATR] dominant whereby the [+ATR] value is active while the [-ATR] value is inert (evidenced by assimilation patterns, coalescence, a.o.). In contrast, incomplete mid harmony systems are canonically [-ATR] dominant in the same contexts. We refer the reader to detailed analysis of these differences in Casali (2003, 2008, 2016).[3]

We designate a smaller subtype of incomplete ATR systems as 'trace ATR systems' (n=20).[4] These are languages which have some properties of synchronic ATR harmony but are not clearly complete ATR systems or mid harmony systems. For example, Mundang [mua] (Adamawa – Elders 2000:55-60) has traces of ATR harmony in the allomorphy of the predicative suffix /-nì/: when attached to focus pronouns, it is realized [-nì] after high [+ATR] /i,u/, [-nè] after mid [+ATR] /e,o/, and [-nɪ̀] after [-ATR] /ɪ,ʊ,a/. In Klao [klu] (Western Kru – Singler 1983), there are clear harmony restrictions with three sets of vowels - expanded /i e o u/, non-expanded /ɪ ʊ/ and low /ɛ a ɔ/. However, such cases cannot be clearly analyzed as ATR harmony, and they show various degrees of variation, exceptions, and other complications. Several Dinka languages of the Nilotic family represent another type of trace system, whereby an ATR distinction has been largely replaced with a contrast between breathy and modal phonation, e.g. in Luac Dinka [dik] (Remijsen & Ladd 2008, Remijsen & Manyang 2009), Agar Dinka [din] (Malou 1988), and Bor Dinka [dks] (Denning 1989:131). Other instances of trace systems show a recent collapse of an ATR system, and display inter-speaker variation, such as the Ijoid languages Defaka [afn] (Jenewari 1983, Shryock et al. 1996/7, Connell et al. 2009) and Nkoroo

[3] Another type of dominance outside of the scope of this paper is root-controlled ATR, whereby the ATR value of an affix assimilates to the ATR value of the root/stem.
[4] Note that this is a more restricted definition of trace systems than we claimed in AUTHORS (2017:6). In that paper, 'trace' referred to all types of incomplete ATR systems.

[nkx] (Obikudo 2008). It may be the case that future work may reclassify these 20 trace ATR systems into the other ATR types.

Note that we do not classify a system as trace ATR simply because it descends historically from an ATR system. For example, several Edoid languages such as Edo [bin] and Esan [ish] (Benue-Congo: Nigeria) descend from Proto-Edoid which is reconstructed with cross-height ATR harmony (Elugbe 1989). Despite this history, these languages are classified as no ATR rather than incomplete ATR because they no longer have any clear vowel co-occurrence restrictions, e.g. the name *Ẹdo* /ɛ̀dó/ 'Edo language/people, Benin City'. Similarly, not all incomplete ATR systems clearly descend from complete ATR systems. Gbaya languages are mostly classified as incomplete mid harmony systems, and even Proto-Gbaya is not constructed with cross-height complete ATR harmony (Moñino 1995). In Chadic, Dangaleat [daa] (East Chadic - Ebobissé 1979:24-25) contains a mid-vowel co-occurrence restriction and is therefore classified as mid harmony, even though there is no evidence for a proto-ATR system in any branch of the Chadic family, complete or incomplete. In total, our classification system is sensitive only to synchronic patterns and not diachronic history.

3.2 Previous areal surveys of ATR

Several previous works have surveyed the areal distribution of ATR across Africa. We summarize here major works in the past two decades. Dimmendaal (2001:368-373) surveys complete ATR harmony systems which demonstrate cross-height harmony, showing that they occur in languages ranging from the Atlantic languages in the far west into East Africa (Figure 5). His survey reveals a West African ATR area and an East African ATR area, with a small number of ATR systems to their north. A large part of Central Africa lying between the two ATR areas lacks complete ATR entirely, a point to which we return in the next section.

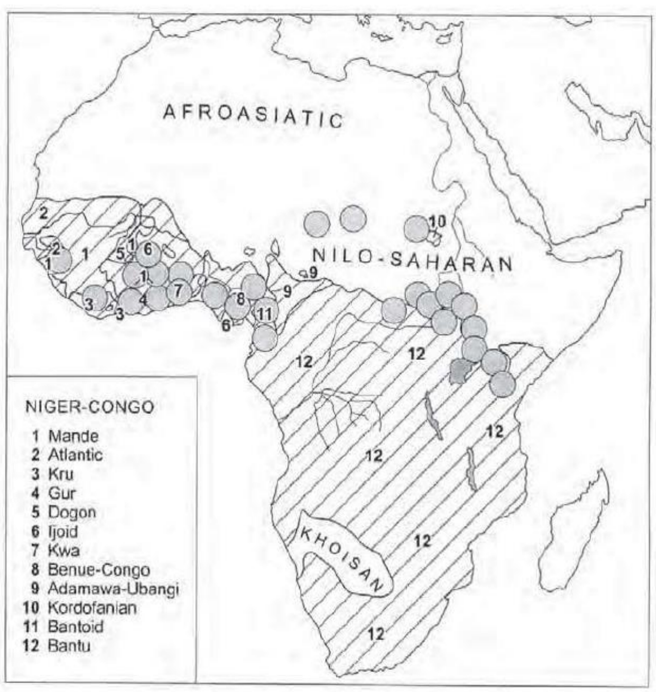

Figure 5: ATR languages are grey circles (Dimmendaal 2001:370)

Although not explicitly surveying ATR's areal distribution, Casali's (2003, 2008) works are the most comprehensive on the properties of ATR in Africa. Casali (2008) surveys both complete and incomplete ATR systems, noting their extensive geographic and genetic distribution within the Nilo-Saharan and Niger-Congo phyla. He explicitly notes that incomplete systems are much more common in West Africa than in East Africa and that [-ATR] dominance/root-controlled dominance is more common there. In contrast, complete ATR harmony systems involving [+ATR] allophones [e o] of [-ATR] /ɛ ɔ/ (our 5Ht[M] - Table 2) are found exclusively in East Africa, with [+ATR] dominance more characteristic of the region. Furthermore, harmonic languages which lack phonemic */e o/ are characteristically [+ATR] dominant, whereas those which lack */ɪ ʊ/ are [-ATR] dominant, a pattern Casali refers to as 'system dependent [ATR] dominance'.

Furthermore, Clements & Rialland (2008:50-53,80-81) discuss the distribution of different ATR types. They note that complete ATR harmony (their 2H type) is concentrated in Mande, Kru, Kwa, Gur, Ijoid, Benue-Congo families (Edoid, Igboid, Cross River) in the west, and Central Sudanic, East Sudanic, Nilotic, and some Kordofanian languages in the east. They also note an absence of ATR among Atlantic families, Gbe, Defoid (i.e. Yoruboid), Idomoid, Platoid, Jukunoid, Bantoid/Northwestern Bantu languages, and Adamawa-Ubangi (except Zandic). They additionally note that complete ATR systems extend well beyond the eastern limit of their proposed Macro-Sudan Belt linguistic area, bleeding into the East and Rift zones (see Figure 2 above).

Finally, Güldemann (2008:158-160, 178) provides an extensive discussion of ATR harmony to support the proposed Macro-Sudan Belt linguistic area (Figure 3 above). Unlike Dimmendaal, Güldemann groups together complete and incomplete ATR systems, and by collapsing these two systems maps a near-continuous band of ATR stretching from Senegal to Ethiopia (Güldemann (2008:60). The only gap is the Mande area centered around Guinea and western Mali, shown in Figure 7 below.

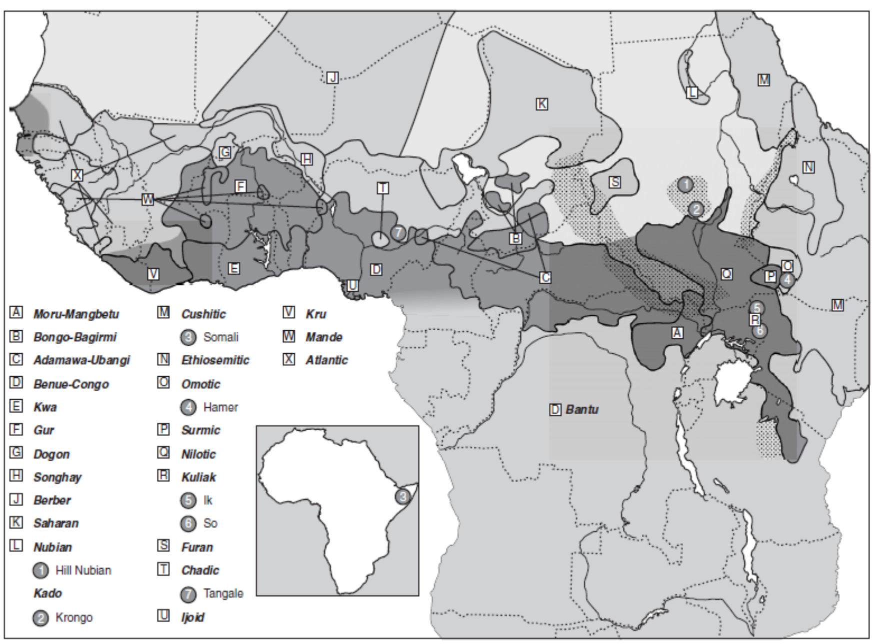

Figure 6: Distribution of ATR in dark grey (Güldemann 2008:160)

When taken together, previous areal-typological surveys demonstrate that ATR is an extremely widespread phonological feature and largely restricted to Sub-Saharan Africa north of the Congo Forest/Bantu Spread Zone, running east-west.

With these studies as our starting point, we can ask a number of questions. What are the precise isoglosses demarcating zones of complete, incomplete, and no ATR? How do we understand the relationship between the western and eastern ATR zones? How much can these patterns be attributed to areal spread versus genetic inheritance? What is the relationship of ATR harmony to other vowel system features? We now turn to our survey of ATR systems to address these issues.

3.3 Areal distribution of ATR in ALFA

Our survey of ATR types reveals the areal distribution in Figure 7, illustrating a number of areal zones.[5] Complete ATR with cross-height harmony occurs mainly in three regions: an Atlantic ATR zone, a West African ATR zone, and an East African ATR zone. The Atlantic ATR zone is the smallest zone, and consists of the small group of blue dots of North Atlantic languages in Senegal and the Gambia. This is the western most concentration of dark blue dots in the figure below. A table providing the breakdown of ATR type by language family is provided in Table 15 in the appendix.

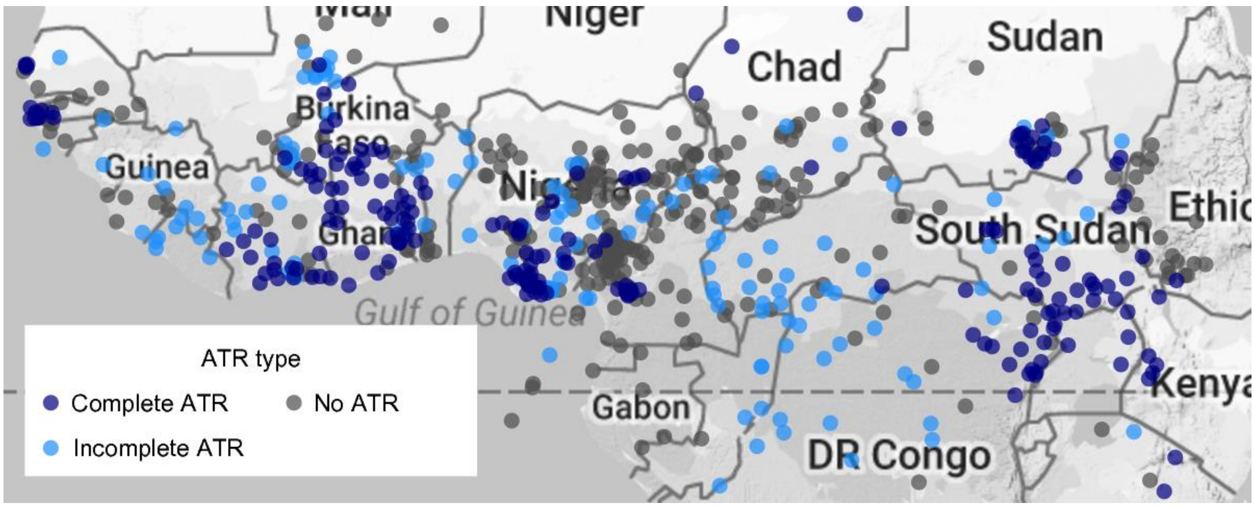

Figure 7: Areal distribution of our survey:
Complete ATR (*n*=217), incomplete ATR (*n*=142), no ATR (*n*=322)

Further east is the West African ATR zone, separated from the Atlantic ATR zone by some distance. A zoomed-in map of the West African ATR zone is provided in Figure 8, with several major languages noted as landmarks. As stated above, complete ATR systems are dark blue circles in this zone.

[5] We use the neutral term ‘areal zone’ in the sense of Clements & Rialland (2008:37), in order not to imply that common features have spread through contact or genetic inheritance.

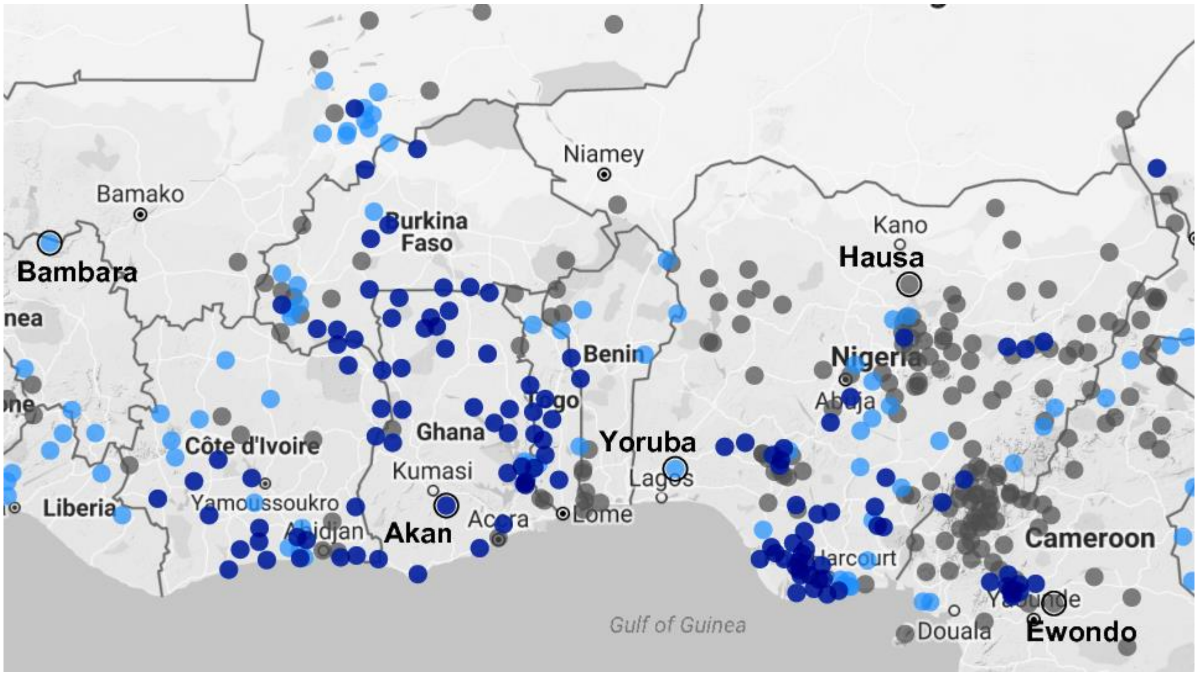

Figure 8: West African ATR zone
(complete = dark blue, incomplete = light blue, grey = no ATR)

This zone encompasses a large portion of the languages spoken near the Gulf of Guinea, stretching from Côte D'Ivoire to Nigeria along the coast and inland into Northern Ghana, Burkina Faso, and Mali. It is genetically diverse, including languages from the families Kru, Mande, Dogon (Bondum Dom [dbu] - Heath 2014), Kwa, Gur, Benue-Congo, Ijoid, Adamawa, and Chadic (Tangale [tan] – Kidda 1993). The western part of the West African ATR zone centered around Ghana is more uniform in having complete ATR than is the eastern part in Nigeria, where there is less uniformity. Note also that in the middle of the West African ATR zone is a sub-areal zone which systematically lacks complete ATR, comprised of Gbe, Yoruba/Defoid, Edoid, Kainji, and East Mande languages.

The third zone of complete ATR is the East African ATR zone, stretching from the Kordofanian languages in the Nuba Mountains of southern Sudan southward into Uganda and Kenya, shown in detail in Figure 9.

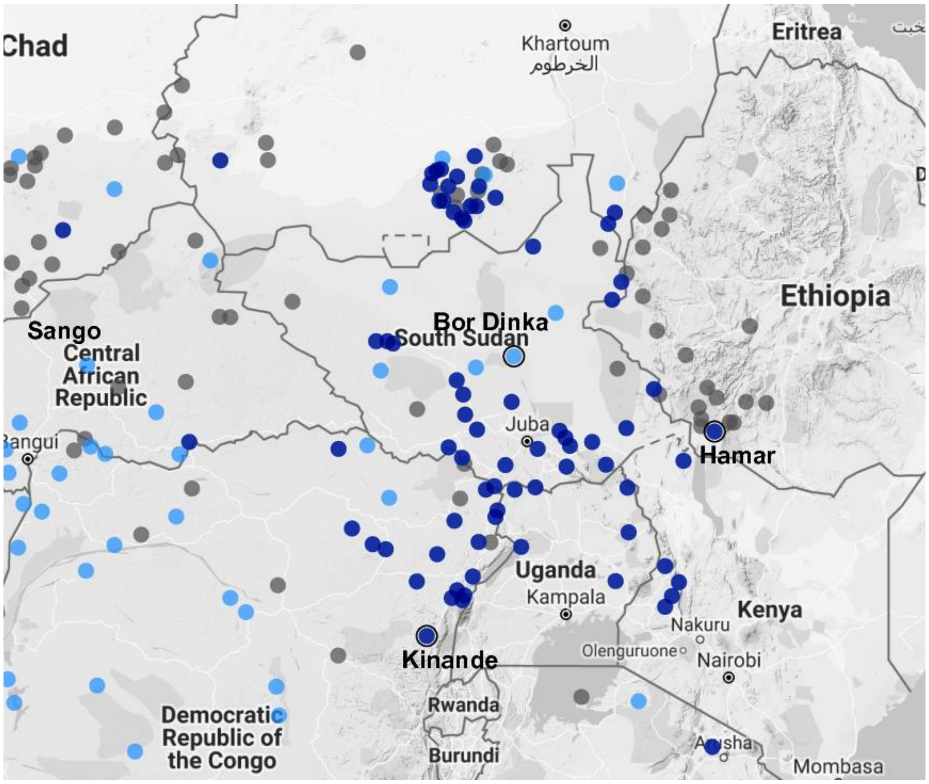

Figure 9: East African ATR zone
(complete = dark blue, incomplete = light blue, grey = no ATR)

This zone is also genetically diverse, including languages from Kordofanian families (e.g. families Talodi-Heiban, Temein, a.o.), Nilotic, Surmic, Central Sudanic, other Nilo-Saharan families (Eastern Sudanic, Kadugli-Krongo, Nubian), Bantu, Ubangian, and South Omotic. Notice that several languages in the central part of this zone in South Sudan do not have complete ATR, which includes many Nilotic languages.

There are four significant complete ATR outliers which fall outside of these three complete ATR zones. One is the Mbam family of languages of central Cameroon (Bantu A; Glottocode mbam1252), visible as the cluster of dark blue circles surrounded by grey in the bottom right of Figure 8. The second are the Saharan languages of the sparsely populated areas of northern Chad, which include Beria [zag], Dazaga [dzg], and Kanembu [kbl]. These are seen at the top of Figure 7 within Chad. Finally, two outliers which are at some considerable distance from the East African ATR zone are Malila [mgq] in far southern Tanzania (Bantu - Kutsch Lojenga 2009) and Somali in the far east (Cushitic – Saeed 1999, though see Kimper *et al*. to appear for a critical re-examination). These outliers fall outside of the maps provided.

Our discussion of complete ATR systems in section 3.1 established three subtypes, provided in Table 2. 5Ht systems have phonemic ATR counterparts at both high and mid heights, 5Ht[M] systems have only [-ATR] /ɛ ɔ/ phonemes but have [ATR] counterpart allophones [e ɛ o ɔ], and 5Ht[H] systems have only [+ATR] /i u/ phonemes but have [ATR] counterpart allophones [i ɪ u ʊ]. The map in Figure 10 below shows that the latter two systems are found in distinct zones.

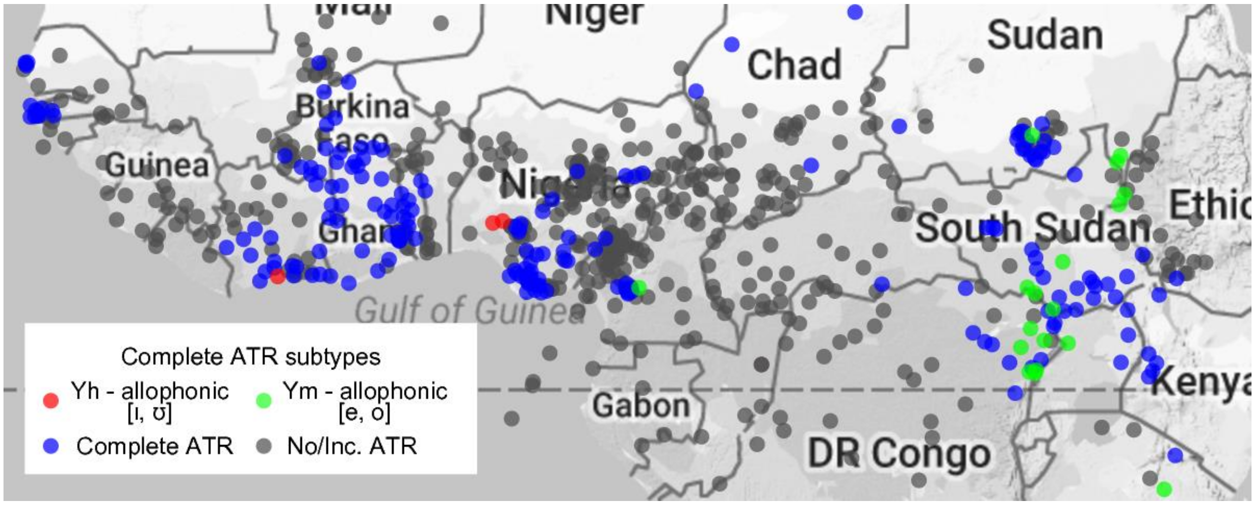

Figure 10: Distribution of complete ATR subtypes

The blue dots represent complete ATR 5Ht systems with a full set of high and mid phonemes. Red dots indicate 5Ht[H] languages without /ɪ ʊ/, and occur entirely in the West African ATR zone and absent in East African (previously noted by Casali 2003:362, and Rose 2018). In contrast, green dots are 5Ht[M] languages without /e o/ and are almost entirely in the East African ATR zone. The only outlier is the Mbam language Tuki [bag] (Boyd 2015). Here, [e] is an allomorph of /ə/ and [o] is an allomorph of /ʊ/, a situation quite distinct from [e o] allophony in East Africa (as described in section 3.1).

Further, these figures (Figure 7-Figure 10) also show that there are numerous regions in our survey which systematically lack complete ATR, consisting principally of incomplete and no ATR systems. We collapse these two classifications together as ‘ATR-deficient’ zones. One such region is the Guinean ATR-deficient zone, which includes many Kru and Mande languages around the country of Guinea and surrounding environs. The Guinean ATR-deficient zone constitutes the large area between the Atlantic and West African ATR zones we noted earlier. This is seen clearly in Figure 7 and Figure 10.

The second is the Central African ATR-deficient zone, visible as the predominantly gray area running north-south between Chad and the Democratic Republic of Congo in Figure 7-Figure 10. The Central African ATR-deficient zone lies between the West African and East African ATR zones. Like the West and East African ATR zones, the Central African ATR-deficient zone is genetically heterogeneous, composed of Niger-Congo families (e.g. Grassfields Bantoid, Bantu, Delta Cross, Kainji, Platoid, Jukunoid, Adamawa, Gbaya, Ubangi), Nilo-Saharan families (Sara-Bongo-Bagirmi, Dajuic, Maban), and Afroasiatic families (all four Chadic sub-groups).

The consistency of complete ATR systems begins to break down at the boundary of the West African ATR zone and the Central African ATR-deficient zone. Systems with mixed properties are common here. For example, Hone [juh] (Jukunoid - Storch 1999) at the border of Nigeria and Cameroon is classified as complete ATR, having cross-height harmony between /i e o/ and /ɪ ɛ ɔ/. However, this language lacks a [–ATR] counterpart to [u] which is ‘neutral’ (Storch 1999:65). In Hone, the phonemes /ə/ and /a/ also do not form an ATR pair, and are also neutral. Further, Mundang [mua] (Adamawa – Elders 2000) further east has lost its active ATR system, retaining only traces of it (as discussed in section 3.1 above).

The reader should note that our calling ATR-deficient zones areal ‘zones’ is somewhat of an abstraction since the absence of ATR extends to all languages of Africa not indicated on these maps, i.e. Afroasiatic languages to the North and East and Bantu and ‘Khoisan’ to the South. In total, however, our survey corroborates earlier survey work in Dimmendaal (2001) in that an extremely vast area of Central Africa categorically lacks complete ATR harmony of the cross-height type.

Compared to complete ATR systems, the different subtypes of incomplete ATR and no ATR systems which make up the languages of the ATR-deficient zones are not consistently distributed. This is seen in Figure 11 below.

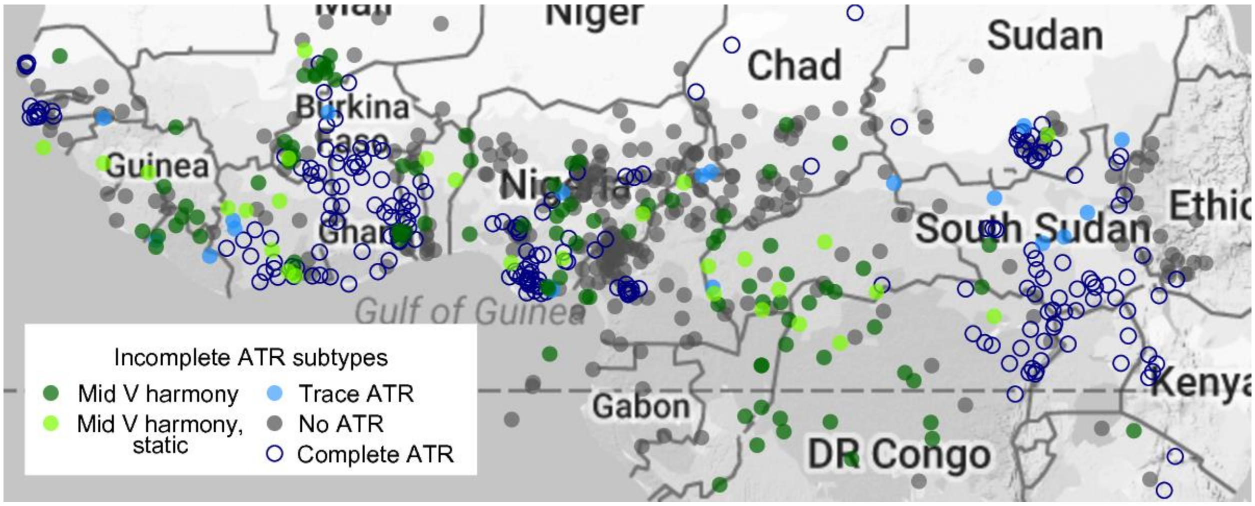

Figure 11: Incomplete ATR subtypes

Mid harmony languages are designated by dark green dots (*n*=94). Those languages for which there is positive evidence that mid harmony is restricted to roots are designated as static mid harmony in light green (*n*=28). Trace systems are in light blue dots (*n*=20), no ATR are in grey (*n*=322), and complete ATR systems are transparent with blue outline. Moving west to east, the Guinean ATR-deficient zone contains all four types of incomplete ATR systems. The larger Central African ATR-deficient zone consists primarily of mid harmony systems and no ATR systems, with mid harmony more common starting from Gbaya languages in western Central African Republic, moving southward into Bantu languages in Congo-Brazzaville and the Democratic Republic of Congo (Leitch 1996, Hyman 1999).

We should emphasize that although there are large areas of the Macro-Sudan Belt which lack complete ATR, other forms of vowel co-occurrence restrictions and harmony are widespread. We have already mentioned widespread Mid harmony. Rounding and back harmony is also widespread across the Macro-Sudan Belt, albeit less extensive than well-known counterparts outside of Africa, e.g. in Turkic languages.[6] Vowel co-occurrence restrictions are especially prevalent within the Central African ATR-deficient zone, and nearby areas. Boyd (1989: 198) summarizes Adamawa and Ubangi family vowel systems as ‘often associated with “redundancy rules”, which accept sequences of identical vowels, define (and usually accept) sequences of maximal difference, and require one or more common features (front/back, open/closed) as a condition of admissibility for any other sequence of non-identical vowels’, e.g.

[6] Rounding harmony to some extent exists in Tommo So [dto] (Dogon: Mali - McPherson & Hayes 2016), Alladian [ald] (Kwa: Ivory Coast - Duponchel & Mel 1983), Kalabari [ijn] (Ijoid: Nigeria - Akinlabi 1997), Samba-Leko [ndi] (Adamawa: Nigeria - Fabre 2002), Laal (isolate: Chad – AUTHOR 2 2017), Kera (Chadic: Chad – Pearce 2013: 85-87,) Iceve-Maci [bec] (Bantoid: Cameroon - Cox 2013), Punu [puu] (Bantu - Hyman 2008:329-330), Zande [zne] (Ubangi: Central African Republic - Tucker 1959; R. Boyd 1995), and Southwest Gbaya [gso] (Ubangi: Central African Republic - Moñino 1995:86-92, 99-104), among others.

in the Adamawa language Kare [kbn] (Lim 1997:95-98). Examples of typical co-occurrence restrictions outside of Adamawa/Ubangi are provided in Table 6-Table 5 below from Kaba [ksp] (Sara-Bongo-Bagirmi - Moser 2004:40) and Agwara Kambari [asg] (Kainji - Stark 2000:57; AUTHOR 1, field notes).

V2 / V1	i	e	ɛ	a	ə	u	o	ɔ
i	✓	-	-	✓	-	-	✓	-
e	-	✓	-	-	-	-	✓	-
ɛ	-	-	✓	-	-	-	-	-
a	✓	-	✓	✓	✓	-	✓	✓
ə	-	-	-	-	✓	-	-	-
u	✓	✓	-	✓	-	✓	-	-
o	-	✓	-	-	-	-	✓	-
ɔ	✓	-	✓	-	-	✓	-	✓

Table 6: Kaba vowel co-occurrence restrictions

V2 / V1	i	u	ɘ	e	o	a
i	✓	✓	✓	✓	✓	✓
u	✓	✓	✓	✓	✓	✓
ɘ	✓	✓	✓	-	-	-
e	✓	✓	-	✓	-	-
o	✓	✓	-	-	✓	-
a	✓	✓	-	-	-	✓

Table 5: Agwara Kambari restrictions

Kaba demonstrates a mid vowel co-occurrence restriction, but is part of a larger system restricting vowel co-occurence generally. Agwara Kambari makes no contrast between mid vowels, but has a robust harmony system restricting non-high vowels /ɘ e o a/ to co-occurring only with high vowels or a non-high vowel of the same quality, exhibiting both static and dynamic patterns.

Further, a number of Central African languages show a propensity towards having identical vowels within roots or stems, a type of 'total harmony'. For example, while Berom [bom] (Platoid: Nigeria) has a seven vowel system approximately 80% of all disyllabic stems having identical vowels (Bouquiaux 1970:98-99). Similar facts are noted for Sara languages (Central-Sudanic – Keegan 1995), Banda-Ndele [bfl] (Ubangi - Sampson 1985:141) where 47% of CVCV words have identical vowels, and C'Lela [dri] (Kainji: Nigeria - Dettweiler 2015:28) where approximately 61% (158/260) of disyllabic stems have identical vowels. Outside of Central Africa, similar facts have been reported for West African Mande languages, e.g. Bambara [bam] (Dumestre 2003:18-21) and Mano [mev] (Khachaturyan 2014:18).

4 Interiority

4.1 Background and previous areal surveys of interiority

This section discusses the distribution of interiority in the Macro-Sudan Belt. Interior vowels are defined as vowel qualities within the interior regions of the vowel space as characterized by the International Phonetic Alphabet, and are typically associated with formant frequencies that are less extreme than peripheral vowels. Interior vowels include front rounded vowels, all non-low central vowels, and unrounded non-low back vowels. Interior vowels compared to peripheral vowels are summarized in (3) below.

3.	Vowel quality distinctions	Front	Central	Back
	Interior	[y ʏ ø œ	ɨ ɪ ʉ ɘ ɵ ə ɜ ɞ ɐ	ɯ ʊ̜ ɤ ʌ]
	Peripheral	[i ɪ e ɛ æ	a	u ʊ o ɔ ɑ ɒ]

One of the motivations for assessing interiority rather than merely central vowels is that it allows us to group together high vowels /ɨ ʉ ɯ/ of different values for backness (and likewise mid vowels /ə ɘ ɤ ɜ ʌ/), and thereby avoid debate as to which IPA symbol best captures their phonetic quality. For example in Tumak [tmc] (East Chadic: Chad), there is interspeaker variation in the realization of /ə/ as [ə] or [ɤ] and /ɨ/ as [ɨ] or [ɯ], making it an arbitrary decision on which to promote as the phonemic representation. Crucially for our purposes, both are interior phonemes which form a minimal pair (/jə̄gə̄n/ 'insult' vs. /jɨ̄gə̄n/ 'to measure' - Caprile 1977:84).

Interior vowels are a well-known feature of many language families in Central Africa, such as Bantoid (Watters 1989:414) and Chadic (Gravina 2014:147). Many Central African languages have more than one interior vowel, e.g. as in Tumak above. Further, in Kejom [bbk] (Grassfields: Cameroon - Akumbu & Fogwe 2012), three interior phonemes /ɨ ʉ ə/ contrast, found in the following minimal pair (also including peripheral vowels):

4. Kejom minimal pair with interior vowels /ɨ ʉ ə/, versus peripheral vowels /i e u o/

/i/	tʃî	'in-law'	/ɨ /	tʃɨ̂	'fireplace'	/ʉ/	tʃʉ́	'spit'	/u/	kə̀ntʃù	'wildcat sp.'
/e/	tʃê	'minimize'	/ə/	tʃə́	'kick'				/o/	tʃô	'pass'

Although interiority is known as a feature of several families of Central Africa, to our knowledge the only survey of interiority in this region is Thomas *et al*. (1973), focusing on families within Niger-Congo and Nilo-Saharan. We show their map of interiority in Central Africa in Figure 12 below, coloring in the regions in pink which they designated as having interior vowels for maximal clarity.

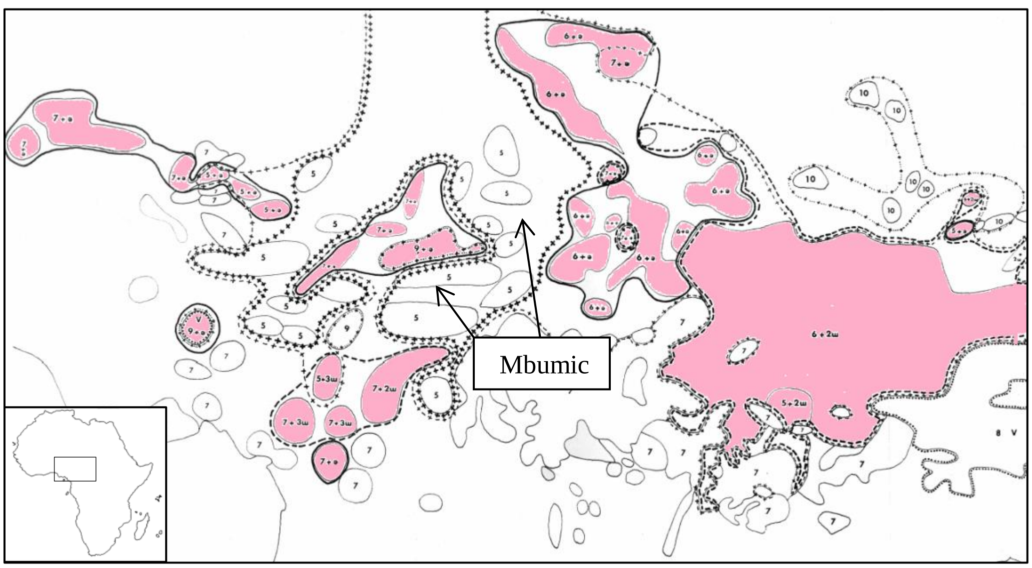

Figure 12: Map of interior vowels in NC and NS phyla - Thomas et al. (1973:136)[7]

Although Thomas et al. limit their survey to the Niger-Congo and Nilo-Saharan phyla (i.e., not surveying Chadic), they still demonstrate that interiority is found across a large range of Central Africa. They overtly note its presence in the families of Kainji, Plateau, Cross River, Bantoid,

[7] Codes for interior vowels map (Thomas et al. 1973):

++++++++	5-7 vowel qualities
+-+-+-+-+-	5-6/7-8 peripheral vowels
+…+…+…	9-10 peripheral vowels
…………	ATR contrasts
_________	Only one interior vowel
-------------	2 or more interior vowels

Adamawa (e.g. Samba Leko, Vere), Ubangian (e.g. the Bandaic subgroup), and Sara-Bongo-Bagirmi.

In every family, however, there are individual languages which lack interior vowels, for instance a number of Ubangian and Adamawa languages. Highlighted on the map is an Adamawa branch 'Mbumic' (their 'Dama-Kari') without interior vowels occurring in the heart of Thomas et al.'s interiority zone, including languages Dama [dmm], Mono [mru], Mambay [mcs], Mbum [mdd], Laka [lak], Tupuri [tui], among others.

4.2 Areal distribution of interiority in ALFA

We discuss here the areal distribution emerging from our survey of interiority in the Macro-Sudan Belt. Our survey catalogues both phonemes and allophonic variants, and by doing so we are able to capture the presence of interiority at different levels of representation. For example, /i/ is realized as [ɨ] in closed syllables in Horom [hoe] (Platoid: Nigeria – Nettle 1998), which otherwise does not exhibit interior vowel qualities in its inventory. Moreover, it is well known that interior vowels may act as reduced allophonic variants of peripheral vowels cross-linguistically, e.g. realized as [ə] in a non-prominent position, or act as an epenthetic vowel.

Our survey distinguished between two roles for the central mid interior vowel (e.g. /ə/ or /ɜ/) in vowel systems. One type is a [+ATR] vowel often represented as /a̹/ but often just /ə/. In this first type, although the vowel is phonetically an interior vowel, phonologically we treat it as a peripheral low vowel, due to its behavior as the counterpart to the low peripheral [-ATR] vowel /a̹/. The second type is a central vowel (again, /ə/ or /ɜ/) which is *not* the counterpart of /a/ in an ATR system. In this second type, we treat it as a fully-fledged interior vowel. In order not to conflate the two (which would artificially increase the number of languages with both ATR harmony and interior vowels), we mark languages where the only 'interior' vowel is [+ATR, +low] /ə/ as a special case in our database.[8]

Interiority is encoded in our database with the following values:

5. Interiority coding
   a. Phonemic (*n*=204) – Has at least one phonemic interior vowel
   b. Non-phonemic (*n*=83) – Has at least one allophonic interior vowel (and no phonemic ones)
   c. [+ATR, + low] (*n*=69) – The only interior vowel is /ə/ which is [+ATR, +low]
   d. None (*n*=325) – Has no interior vowels entirely

The geographic distribution of these levels of interiority is shown in Figure 13. Approximately half of the language varieties surveyed had at least one interior vowel at some level of representation, and the remaining half did not. A table providing the breakdown of interiority type by language family is provided in Table 15 in the appendix.

[8] In most complete ATR languages which have both /ə/ and /a/, the two behave as [+ATR]/[-ATR] counterparts, e.g. in the Degema examples in examples (1-2). However, in the ATR harmony found in Akebu [keu] (Kwa – Koffi 1981, Storch & Koffi 2000), both /ə/ and /a/ exist but they are not ATR counterparts to one another (they are both neutral and appear with either ATR set). In these few cases, we classify /ə/ as interior and the language therefore as having interiority, even if /ə/ is the only interior vowel.

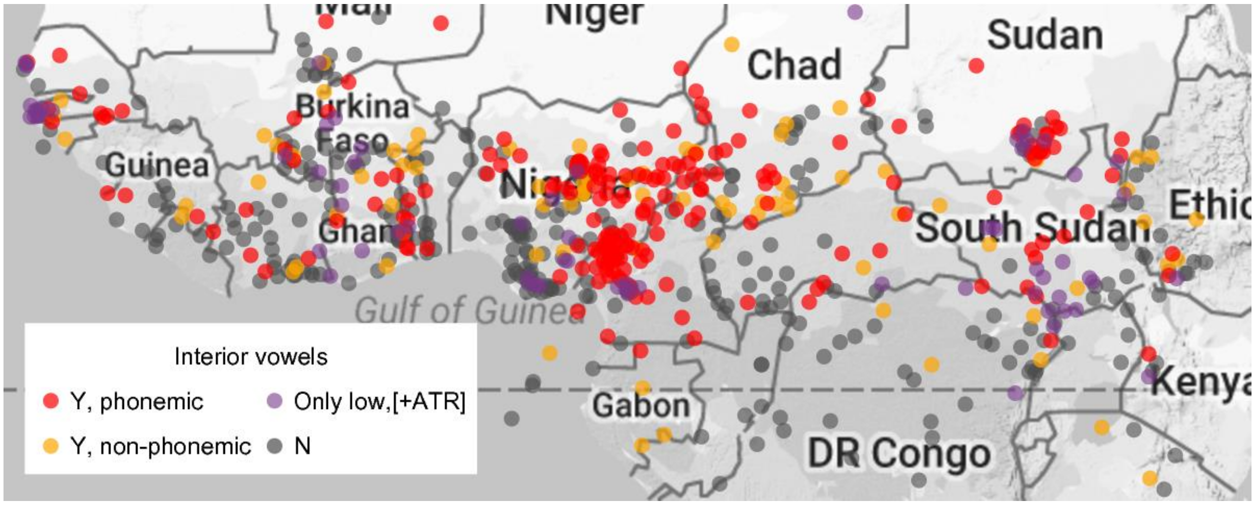

Figure 13: Geographic distribution of interior vowels in Macro-Sudan Belt

From this map, we see that the largest concentration of phonemic interior vowels (in red) is found in Central Africa, what we term the Central African interior vowel zone. Languages of this area almost categorically have phonemic interior vowels. This zone encompasses languages of southern Chad moving into Nigeria and Cameroon, a linguistic area with one of the highest concentrations of language varieties in Africa. It forms the confluence of three of the four Greenbergian stocks, and includes the families of Grassfields Bantu, Delta-Cross, Adamawa, Ubangian, Kainji, Platoid, Jukunoid, Biu-Mandara Chadic, West Chadic, Masa Chadic, and Sara-Bongo-Bagirmi. The density of phonemic interior vowel systems thins at the edges in southwestern Nigeria (Benue-Congo and Ijoid families) and in the Central African Republic (Gbaya and Bantu families). One of the ramifications of our interiority survey is explicitly linking those Chadic languages in Chad and Northern Nigeria/Cameroon to the Niger-Congo phylum Bantoid and Delta Cross families towards the south.

The Central African interior vowel zone is a prominent area of interiority which manifests in a number of ways other than merely contrastive phonemes. Biu-Mandara Chadic languages are famous for having the typologically unusual phonemic system /ɨ a/, which Schuh (2017) calls the 'Minimal System' in Chadic typology. However, they appear as more typical vowel systems when allophony is taken into account, e.g. [i e ɨ a u o] allophones conditioned by adjacent consonants/consonantal prosodies. Further, Sara languages are well known for robust vowel restrictions within words, but interior vowels are often 'freer' in that they often co-occur with all vowel qualities word-internally (Keegan 1995).

Moreover, a large number of languages in this Central African interior vowel zone have non-contrastive interior vowel allophones of peripheral vowels. For example, descriptions of Ibibio [ibb] (Delta Cross) vary as to whether interior vowels [ɨ ʉ ə ʌ] are phonemic, likely reflecting dialectal differences (Urua 2000:30). At the surface level, however, Urua notes that they all occur in 'General Ibibio' as conditioned variants of /i u o/ respectively: /kím/ 'sew' [kɨ́m]~[kə́m], /ùkù/ 'fox-like animal' [ùkù]~[ʉ̀kʉ̀], and /kpók/ 'cut into pieces (with a knife) [kpók]~[kpə́k]. A comprehensive list of languages showing interior allophony is in Table 16 in the appendix.

Epenthesis of interior vowels is also widely attested in languages of this zone, e.g. in the Sara family (Kenga, Mbay, Sar), among other families. Further, in a number of languages the inventory of interior vowels is increased due to interior allophones of phonemic interior vowels. For example, due to word-level palatal and labial prosodies, phonemes /ə~ɨ/ and /a/ in Mada [mxu] have interior allophones [y] and [ø] respectively (Biu-Mandara, Chadic; Barreteau &

Brunet 2000). In Kom [bkm], coalescence between sequences of vowels results in additional surface interior vowels, e.g. /ui/ > [y] and /oɯ/ > [ø] (Grassfields Bantu; Schultz 1993, AUTHOR 3 field notes).

One noteworthy observation is that despite the prominence of interior vowels, we found no clear case in which /ɯ/ is the sole high back vowel to the exclusion of /u/. This type of system is famous for example for the Japanese phonemic inventory /i e a o ɯ/, where the final vowel is phonetically unrounded [ɯ]~[ṵ̈]~[ṳ]~[ṳ̈]~[ṳ̈] (Okada 1999:118), and is the sole high back phoneme. Of languages containing [ɯ], systems like Japanese where /ɯ/ and /u/ do not contrast constitute approximately 40% of Schwartz et al.'s (1997:247) analysis of the UPSID database. It is therefore interesting to note that African languages of Central Africa do not demonstrate this system. The only potential example in Africa is Pökoot [pko] (Nilotic: Kenya/Uganda - Tucker 1964, Hall et al. 1974) where the vowel quality [u] is only attested as an allophonic variant of /ɨ/.

Let us return to Figure 13 above. Additional concentrations of red dots indicating phonemic interior vowels are also found in an East African zone encompassing the Nuba Mountains of southern Sudan moving into South Sudan, at the border between eastern Ghana and Togo, and sporadically in the remainder of West Africa. Our survey further reveals that there are several languages with non-phonemic interior vowels (orange dots) in the corridor connecting the Central African interior vowel zone and interior vowels in East Africa. In general, however, the distribution of interiority is less geographically concentrated when compared to ATR.[9]

Those languages whose only phonemic interior vowel was [+ATR] /a̠/ (the purple dots in the map) are found in five main regions, but do not occur in a concentration sufficient to warrant a uniquely named areal zone: (1) an Atlantic region in Senegal and the Gambia, (2) an area stretching north-south from southern Ghana to Burkina Faso, (3) the delta region of Southern Nigeria, (4) a small pocket in central Cameroon consisting entirely of the Mbam languages (Bantu - mentioned above in section 3.3), and (5) an area in East Africa in Sudan, South Sudan, and their borderlands, intermixed with phonemic and non-phonemic interior vowel languages.

To conclude this section, it is important to note that a great number of languages we surveyed lack any reported interior phones altogether. Most conspicuous is the large concentration of grey circles in West Africa extending from Sierra Leone and Guinea into southwestern Nigeria, including certain languages from families Atlantic, Songhai, Gur/Senoufo, Dogon, Mande, Kwa, Benue-Congo, and Ijoid. Additionally, many languages south of the prominent interior vowel zones in Central and East Africa lack interior phones altogether, e.g. in much of Bantu. However, we also acknowledge that interiorization is expected given universal phonetic pathways of vowel reduction, and that such reduction may go un(der)reported in phonological descriptions (especially under elicitation). With finer phonetic descriptions of African languages in the future, we expect to assess interiorization both qualitatively and quantitatively (e.g. degree of interiorization, use in different speech styles, number of contexts, frequency of reduction, *etc*.).

[9] Non-phonemic interior vowels are also found in other parts of Africa such as in western Africa. Examples are from a variety of families including Mande, e.g. Guinean Kpelle [gkp] where /i/ and /e/ surface as [ɨ] and [ə] (cf. long /ii/ [ii], /ee/ [ee] - Konoshenko ms.), Kwa, e.g. Abe [aba] where /e/, /o/ have an allophone [ə] (Dumestre 1971, N'guessan 1983) and Nawuri [naw] with centralized allophones /i/>[ɨ], /ɪ/>[ɪ̈], /e/>[ɘ], /ɛ/,/a/ > [ɜ], /a/>[ɐ] (Casali 1988, 2002, Snider 1989, Lange 1996), and Gur/Senoufo languages, e.g. Cebaara Senoufo [sef] involving centralization of short vowels /i/ > [ɨ], /e/ > [ə], /a/ >[ʌ] (Mills 1984:99).

5 ATR x Interiority

5.1 Comparison of ATR and interiority distributions

This section examines the relationship between ATR and interiority in our ALFA database. Observationally, many ATR languages do not have interior vowels (other than [+ATR] /ə/, when present), and at the same time many languages with phonemic or non-phonemic interior vowels do not have ATR. The maps presented above thus highlight one of the most interesting findings of our survey: the Central African interior vowel zone largely lines up with the Central African ATR-deficient zone, and does not significantly overlap with the West African ATR zone to its west or the East African ATR zone to its east.

Their co-occurrence is not impossible, however, and several languages in Africa do exhibit elaborate vowel systems with full sets of [ATR] contrasts for front, central, and back vowels. Examples below come from three genetically unrelated languages spoken at a great distance from one another: Guiberoua Bété [bet] (Kru: Côte d'Ivoire - Marchese 1983), Kanembu [kbl] (Saharan: Chad - Jouannet 1982), and Tima [tms] ('Kordofanian'/Katla-Tima: Sudan – Bashir 2013). All three languages have a contrast between [+ATR] /ɨ/ and [-ATR] /ʉ/~/ɘ/, and the first two also contrast a non-high interior pair [+ATR] /ə/ vs. [-ATR] /ʌ/.

[ATR]	Front	**Central**	Back
+	i	**ɨ**	u
-	ɪ	**ʉ**	ʊ
+	e	**ə**	o
-	ɛ	**ʌ**	ɔ
Ø		a	

Table 7: Guiberoua Bété

[ATR]	Front	**Central**	Back
+	i	**ɨ**	u
-	ɪ	**ʉ**	ʊ
+	e	**ə**	o
-	ɛ	**ʌ**	ɔ
Ø		a	

Table 8: Kanembu

[ATR]	Front	**Central**	Back
+	i	**ɨ**	u
-	ɪ	**ɘ**	ʊ
+	e	**ʌ**	o
-	ɛ	a	ɔ

Table 9: Tima

Families with interior ATR contrasts include Atlantic (Jola-Fonyi [dyo]), Kru (Jluko Godie [god]), Kwa (Gonja [gjn]), Gur (Lama [las]), and 'Kordofanian'/Talodi-Heiban languages (Acheron [acz]), Dagik [dec], Tocho [taz]). The Nilotic language Pökoot [pko] represents a special case of the intersection of ATR and interiority. Long vowels maintain ATR contrasts in the periphery of the vowel space. However, short peripheral vowels have become centralized such that [+ATR] *i,*u,*e have become [+ATR] /ɨ/ and [-ATR] *ɪ, *ʊ have become [-ATR] /ə/ (Tucker 1964, Hall et al. 1974:248).

To further examine this relationship, we mapped ATR and interiority against each other in four different ways below. This involved grouping the variables of ATR and interiority as 'strict' or 'liberal', defined in Table 10.

ATR	Complete	Incomplete	No		**Interiority**	Phonemic	Non-phonemic	[+ATR] /ə/	None
Strict	+	-	-		Strict	+	-	-	-
Liberal	+	+	-		Liberal	+	+	+	-

Table 10: Strict and liberal designations

Strict ATR represents a positive value only for complete ATR systems, whereas liberal ATR is a positive value for both complete and incomplete ATR systems. Similarly, mapping strict interiority represents a positive value for only those languages with phonemic interior vowels, whereas liberal interiority has a positive value for non-phonemic interior allophones and [+ATR] /ə/, as well.

We begin by showing two maps in the figures below. Figure 14 shows strict ATR by strict interiority, while Figure 15 shows liberal ATR by liberal interiority. Taken together, these two maps represent the criteria expected to yield two extremes in classifying vowel system intersection. In these maps, purple dots indicate those systems with positive values for both ATR and interiority, blue dots are those with only a positive value for ATR, red dots are those with only a positive value for interiority, and grey dots are those languages with neither.

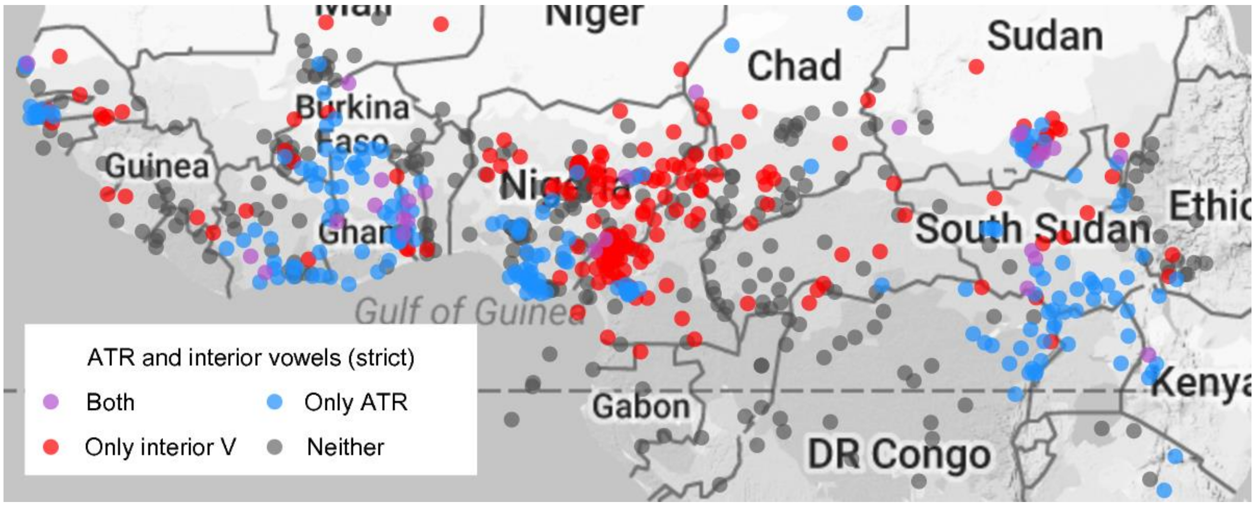

Figure 14: Distribution of strict ATR by strict interiority

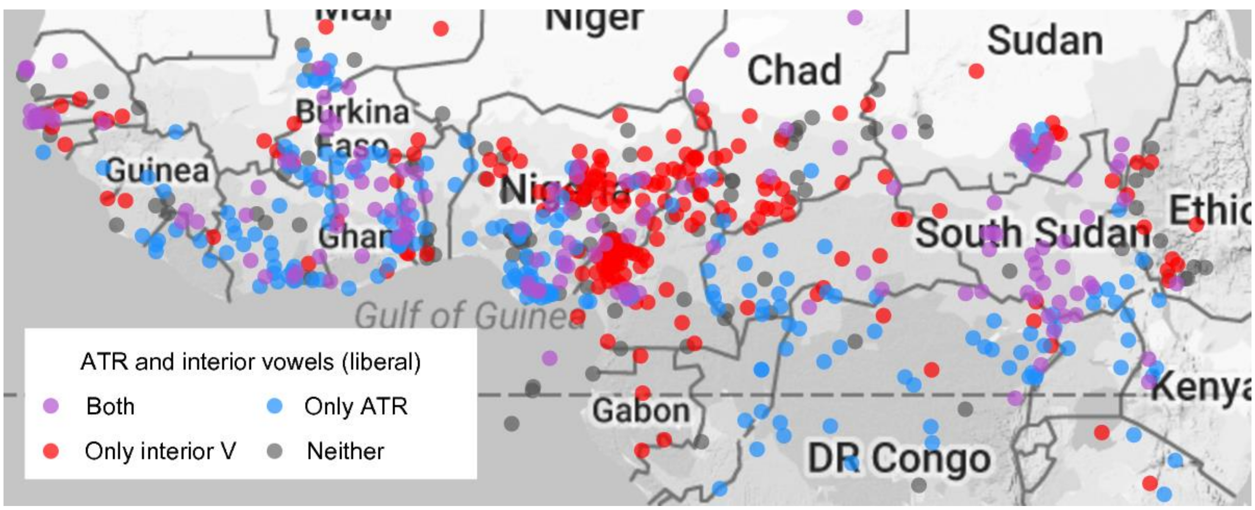

Figure 15: Distribution of liberal ATR by liberal interiority

The strict ATR by strict interiority map in Figure 14 strongly supports the generalization that ATR and interiority do not frequently co-occur. There are a large number of blue dots in the West and East African ATR zones (*n*=188), and a large number of red dots in the Central African interior vowel zone (*n*=175), but only a small number of purple dots indicating a mixed system (*n*=29). Note further the lack of either type in the eastern part of Central Africa (for grey dots in the whole map, *n*=289).

In comparison, the liberal ATR by liberal interiority map in Figure 15 demonstrates that a more liberal definition results in more systems with both ATR harmony and interiority (the purple dots, *n*=150). However, this represents less than a quarter of the surveyed languages, and the numbers of languages with only ATR (blue, *n*=209) and only interiority (red, *n*=206) are still larger. Under the more liberal criteria, systems with both ATR and interior vowels predominantly occur in the West African ATR zone near Ghana, in a transitional zone in Nigeria, and in much of the East African ATR zone.

Two zoomed-in maps of Central Africa are given in Figure 16 and Figure 17 below. As above, certain languages are indicated acting as landmarks.

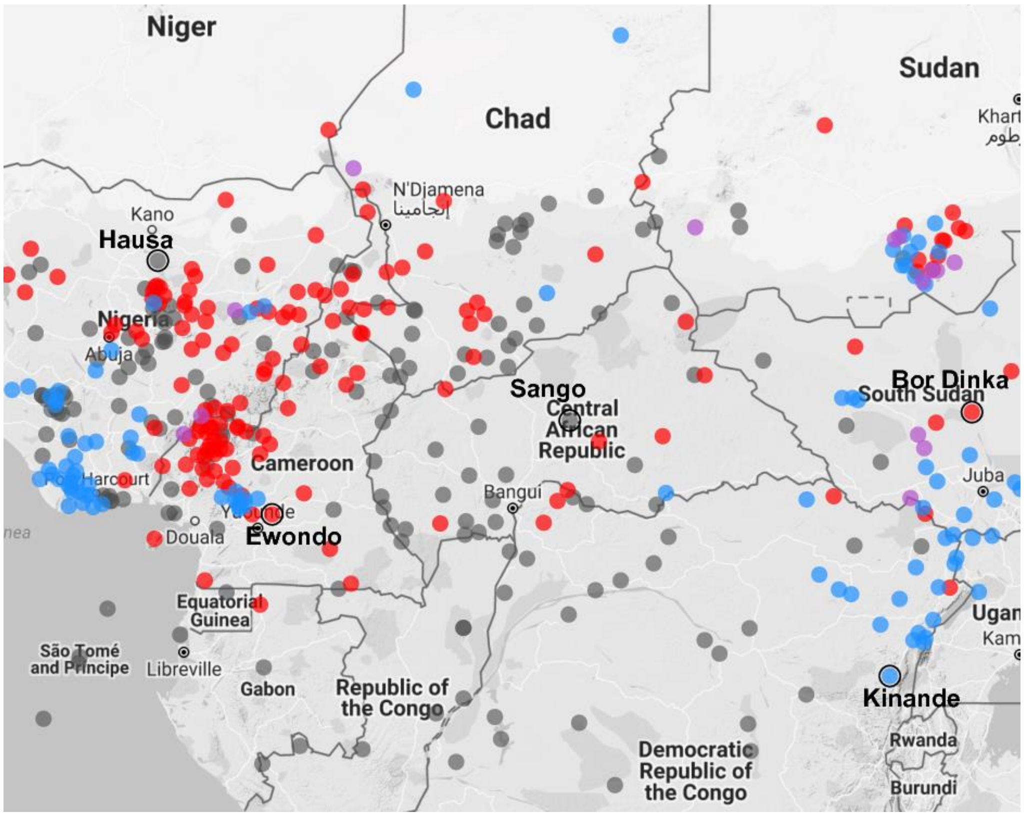

Figure 16: Central Africa – strict ATR by strict interiority
(blue = ATR, red = interiority, purple = both, grey = neither)

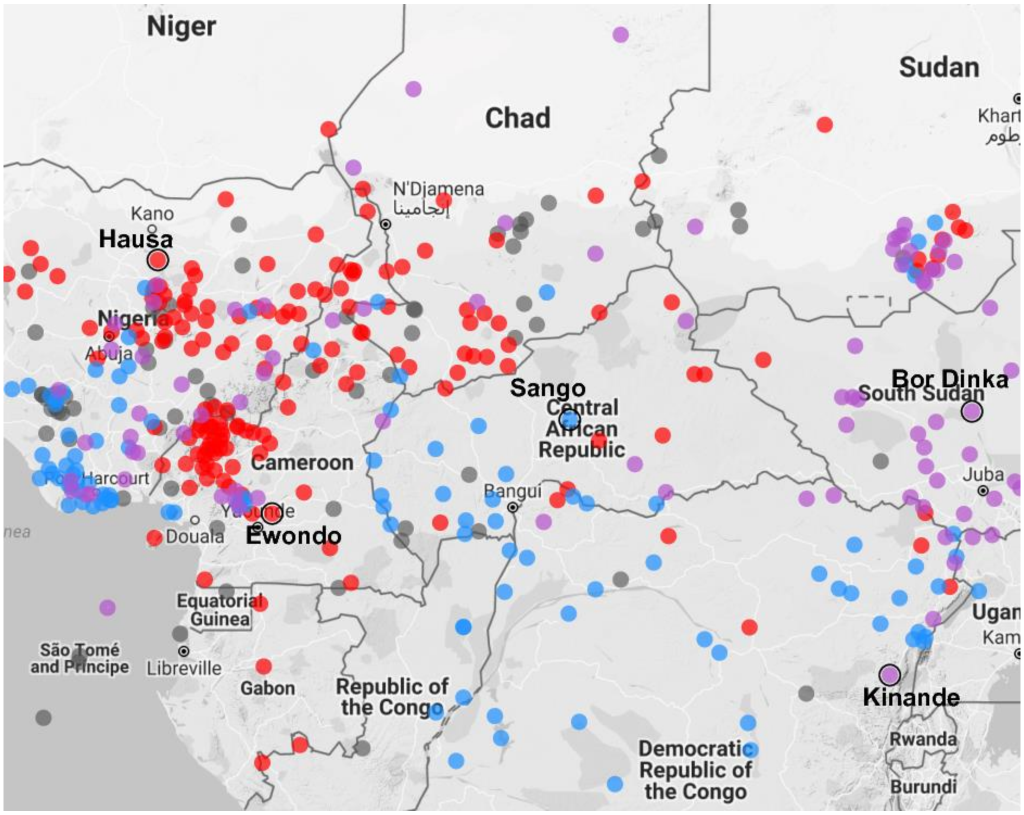

Figure 17: Central Africa – liberal ATR by liberal interiority
(blue = ATR, red = interiority, purple = both, grey = neither)

The first map in Figure 16 represents strict definitions. This map shows that there are a significant number of grey dots in this region, indicating that the Central African ATR-deficient zone is larger than the Central African interior vowel zone. This strict map also illustrates that the East African and West African ATR zones are clearly disconnected. The second map in Figure 17 represents liberal definitions. This map shows that while there are significantly more blue and purple dots in or near the two ATR zones (representing having ATR), there is still a significant number of red dots in Central Africa breaking up the two ATR zones (representing having interiority only). We take this as showing that even under the most liberal interpretation of ATR harmony, there is still a substantial gap in the middle of the Macro-Sudan Belt.

From this distribution we can establish isoglosses which delineate areas with distinct phonological profiles. Using the strict map in Figure 14 which maps only complete ATR systems, the clearest isogloss is in Nigeria, starting from the southeastern-most point at its border with Cameroon, and moving north towards central Nigeria, and then westwards. We term this the Nigerian ATR boundary. Note that the liberal designation in Figure 15 also largely complies with this Nigerian ATR boundary, albeit with purple dots on either side.

Further, the strict map in Figure 14 also shows an isogloss between the Central African ATR-deficient zone and the East African ATR zone, which we call the Sudanese ATR boundary. This boundary is primarily at the border between the eastern edge of the Central African Republic, the western edge of South Sudan, and the northern border of the Democratic Republic of the Congo. This Sudanese ATR boundary is more difficult to delineate precisely due to less linguistic density and less data available generally. This boundary is also largely maintained in the liberal map, albeit with near universal purple dots in South Sudan.

Finally, both the strict and the liberal map show a clear transition zone in Central Africa with respect to interiority. We refer to this isogloss as the Central African interiority boundary. For the most part, it is coextensive with the western and northern borders of the Central African Republic. We do not speculate as to a northeastern-most interiority boundary due to the intermixing of grey and red dots in eastern Chad and the eastern Central African Republic.

5.2 Testing the relationship between ATR and interiority

From these maps, one can reasonably interpret that ATR harmony and phonemic interior vowel qualities are for the most part mutually exclusive, and potentially antagonistic. To assess the nature of this relationship, we performed Pearson's Chi-square (χ^2) tests of independence. Table 11 shows four versions of the test, using either strict or liberal definitions of ATR and interiority.

Strict ATR/ strict interiority	Yes IV	No IV
Yes ATR	29	188
No ATR	175	289
χ^2 = 40.633, p < 0.001 (***)		

Strict ATR/ liberal interiority	Yes IV	No IV
Yes ATR	110	107
No ATR	246	218
χ^2 = .234, p = .6284		

Liberal ATR/ strict interiority	Yes IV	No IV
Yes ATR	55	304
No ATR	149	173
χ^2 = 76.041, p < 0.001 (***)		

Liberal ATR/ liberal interiority	Yes IV	No IV
Yes ATR	150	209
No ATR	206	116
χ^2 = 32.626, p < 0.001 (***)		

Table 11: Pearson's Chi-square tests for the four possible combinations of ATR and interiority variables (strict and liberal)

These tests reveal that strict interiority and ATR (whether liberal or strict) are not independent from one another (i.e. the variables' values are not independent of one another), with $p < 0.001$. This is shown in the two tables in the left column. However, for the liberal definition of interiority (right tables), only liberal ATR harmony is not independent; strict ATR and liberal interiority does not reach significance (p=.6284, top right). Looking at the strict by strict and liberal by liberal, significance is reached, and we therefore take this as supporting a dependent relationship between ATR and interiority.

Furthermore, recall discussion in section 3.1 that first formant frequency (F1) is the major acoustic correlate of ATR, a property it shares with vowel height in non-ATR systems (e.g. English /i/ vs. /ɪ/). Given their similar acoustic profiles, the results in Table 11 may be interpreted in two ways. One is that interiority and ATR harmony specifically are antagonistic. Another is that the presence of vowel contrasts along the acoustic dimension of F1 is antagonistic to the presence of interiority distinctions along the F2 dimension, regardless of how F1 manipulation is articulated or the phonological behavior of contrastive phonemes.

To address this, we repeat the Pearson's Chi-square tests as shown in Table 11 but replacing the strict and liberal ATR harmony variables with strict and liberal variables encoding the presence of mid height contrasts generally, which we call 'mid contrast'. As with ATR, we can distinguish strict mid contrast versus liberal mid contrast. Strict mid contrast indicates that there are two mid phonemes contrasting in height for at least one place of backness, e.g. inventories with /e ɛ o ɔ/, /e ɛ ɔ/, and /ɛ o ɔ/, (but not /e ɔ/). Liberal mid contrast indicates that there is only one mid vowel phoneme at a particular backness value but more than one mid height vowel allophone, e.g. /e o/ > [e ɛ o ɔ].[10] For the mid contrast variable, this does not distinguish between complete ATR, incomplete ATR (e.g. with mid harmony), and no ATR systems. It only codes for presence of absence of these phones.

The results of these four chi-square tests are shown in Table 12. All four show a statistically significant relationship between mid height contrast and interiority; however, the relationship of liberal interiority with respect to liberal mid contrast is relatively weak.

Strict mid contrast/ strict interiority	Yes IV	No IV
Yes mid contrast	129	377
No mid contrast	75	100
$\chi^2 = 17.864$, $p < 0.001$ (***)		

Strict mid contrast / liberal interiority	Yes IV	No IV
Yes mid contrast	242	264
No mid contrast	114	61
$\chi^2 = 14.943$, $p < 0.001$ (***)		

Liberal mid contrast /strict interiority	Yes IV	No IV
Yes mid contrast	159	434
No mid contrast	45	43
$\chi^2 = 20.463$, $p < 0.001$ (***)		

Liberal mid contrast / liberal interiority	Yes IV	No IV
Yes mid contrast	299	294
No mid contrast	57	31
$\chi^2 = 5.764$, $p = 0.0164$ (*)		

Table 12: Pearson's Chi-square tests for the four possible combinations of interiority and mid height contrast variables

At first glance, this table supports the view that the antagonistic relationship is between interiority vs. mid contrast generally. However, further Pearson's Chi-square tests on two subsets of the data point to the opposite conclusion, summarized below.

The first tests include only those languages which do *not* have complete ATR harmony, and therefore retains only languages with incomplete ATR harmony or with no ATR Harmony (*n*=464). The results are shown in Table 13 and reveal that when complete ATR languages are removed from the sample, the relationship between strict mid contrast and strict interiority is still significant but weaker. Further whereas in Table 11 strict ATR by liberal interiority was not significant, in Table 13 it is the liberal mid contrast by liberal interiority which is not significant.

Strict mid contrast/ strict interiority	Yes IV	No IV
Yes mid contrast	106	216
No mid contrast	69	73
$\chi^2 = 9.6473$, $p = 0.001896$ (**)		

Strict mid contrast / liberal interiority	Yes IV	No IV
Yes mid contrast	152	170
No mid contrast	94	48
$\chi^2 = 13.518$, $p < 0.001$ (***)		

Liberal mid contrast /strict interiority	Yes IV	No IV
Yes mid contrast	131	249
No mid contrast	44	40
$\chi^2 = 8.644$, $p = 0.003281$ (**)		

Liberal mid contrast / liberal interiority	Yes IV	No IV
Yes mid contrast	193	187
No mid contrast	53	31
$\chi^2 = 3.7028$, $p = 0.05432$		

Table 13: Pearson's Chi-square tests of mid contrast by interiority
Excludes complete ATR harmony (*n*=464)

[10] Testing two high vowels by interiority would not result in any informative results because virtually all languages with two high vowels surveyed in our database are complete ATR systems. We therefore only test for a relationship of interiority and mid height contrast.

More telling is Table 14 below with an even more restricted data set. This set consists only of those languages with no ATR harmony (*n*=322), removing all complete and incomplete ATR systems. If the relevant constraint were interiority versus the presence of two mid heights (and *not* ATR harmony), then we predict that we should still find a significant relationship after complete and incomplete ATR languages are eliminated from the dataset. Table 14 shows that this is not the case.

Strict mid contrast / strict interiority	Yes IV	No IV
Yes mid contrast	80	102
No mid contrast	69	71
χ^2 =0.70245, p = 0.402		

Strict mid contrast / liberal interiority	Yes IV	No IV
Yes mid contrast	112	70
No mid contrast	94	46
χ^2 =0.84895, p = 0.3568		

Liberal mid contrast / strict interiority	Yes IV	No IV
Yes mid contrast	105	133
No mid contrast	44	40
χ^2 =1.3891, p = 0.2386		

Liberal mid contrast / liberal interiority	Yes IV	No IV
Yes mid contrast	153	85
No mid contrast	53	31
χ^2 = 0.004, p = 0.9496		

Table 14: Pearson's Chi-square tests of mid contrast by interiority
Excludes complete and incomplete ATR harmony (*n*=322)

If all types of ATR harmony language are removed, the relationship between mid contrast and interiority fails to reach significance regardless of strict versus liberal definitions. This shows that it is specifically ATR harmony which has an antagonistic relationship with interiority, rather than a general elaboration of F1 contrasts.

6 Discussion

6.1 ATR zones and a Sudanic 'hotbed'

We have examined the distribution of ATR systems and interiority in the languages of the Macro-Sudan Belt, a proposed linguistic macro-area running East-West South of the Sahara Desert and north of the Congo Rainforest. Within this macro-area, we established five smaller areas which can be coherently defined based on their vowel system profile, shown in Figure 18. At the top of this figure, we repeat the proposed areas from Clements & Rialland's (2008:37) map and Güldemann's (2011:110) map for comparison, in the top left and right respectively.

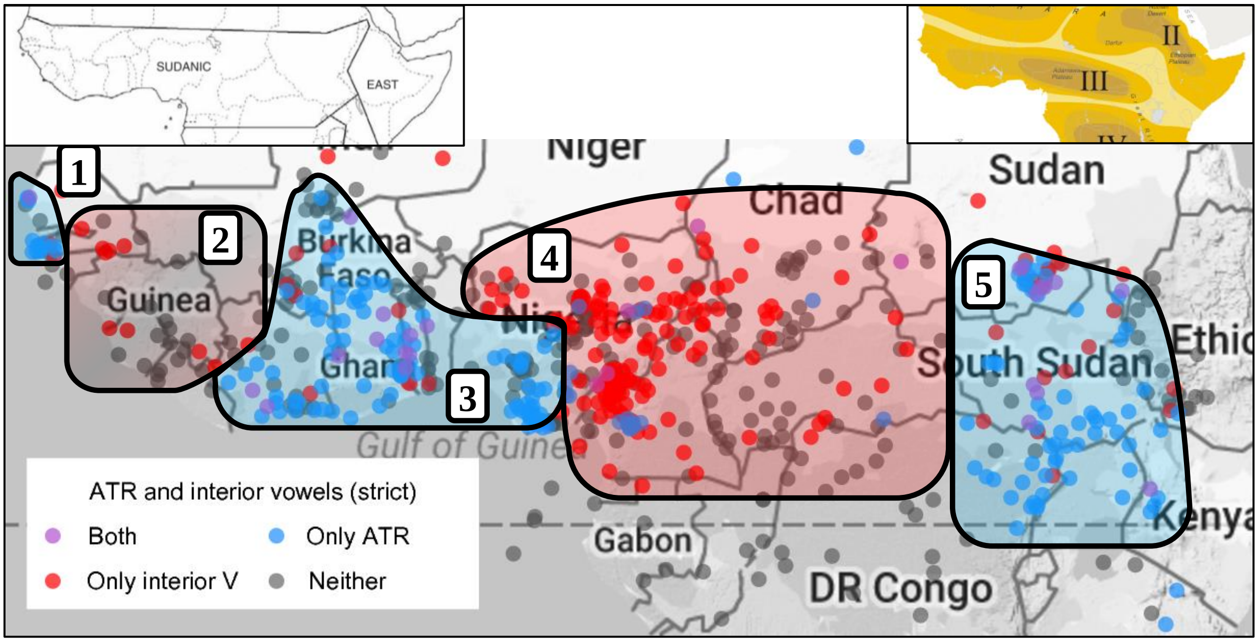

Figure 18: Five areal zones defined by vocalic systems in the Macro-Sudan Belt (map = strict ATR by strict interiority): [1] Atlantic ATR zone, [2] Guinean ATR-deficient zone, [3] West African ATR zone, [4] Central African ATR-deficient zone (includes Central African interior vowel zone), [5] East African ATR zone

The most genetically homogenous and smallest zone among these is the Atlantic ATR zone in the far west and the adjacent Guinean ATR-deficient zone. The next three zones are genetically quite diverse, a definitional criterion for linguistic areas. These are the West African ATR zone, the Central African ATR-deficient zone (including the Central African interior vowel zone), and the East African ATR zone.

We can now ask how findings support or contradict Güldemann's Macro-Sudan Belt hypothesis. In one way our survey supports the existence of this macro-area. Complete ATR harmony of the cross-height variety is found at the far western, the central, and the far eastern regions of the Macro-Sudan Belt zone, and is very rare outside of this zone. Even within those regions in the Macro-Sudan Belt which do not show complete ATR harmony, many languages show incomplete harmony, which is also rare outside of this belt. This confirms this Belt as a macro-area wherein linguistic features spread more easily compared to spreading into other regions, but do not show uniformity.

In another way, however, our results complicate any straightforward understanding of the Macro-Sudan Belt as containing a core 'hotbed' plus a periphery. As introduced above, Güldemann (2008, 2010, 2011) identifies as the 'hotbed' of Macro-Sudan Belt a region centered around Cameroon and the Central African Republic, replicated in the top right of Figure 18 showing the three concentric ovoid shapes. On this hotbed, Güldemann (2008:167) states:

> *"The greatest cohesion exists in an area formed basically by four geographically adjacent language groups: the two easternmost Narrow Niger-Congo families Benue-Congo (minus Narrow Bantu) and Adamawa-Ubangi and the two Central Sudanic families Bongo-Bagirmi and Moru-Mangbetu. …[T]here is only one isogloss in which two of the families do not partake at all or very incompletely: S-(AUX)-O-V-X is not found in Bongo-Bagirmi and great parts of Adamawa-Ubangi. Also, the more western*

Benue-Congo languages are excluded from V-O-NEG and labial flaps. The compact zone consisting of these four families will be called here for convenience the areal "hotbed"."

Our survey reveals that ATR – an otherwise defining macro-area feature of this Belt – is systematically absent in this Central African core. While this does not by itself contradict the existence of Güldemann's hotbed overall, the exclusion of ATR is a striking gap worthy of consideration. One might wonder therefore whether this macro-area has the concentric structure suggested by Güldemann (2008), or if it is simply a continuum of overlapping areas. On the whole, our findings certainly question the idea that linguistic macro-areas necessarily include a core and a periphery.

6.2 Development of ATR and interiority

As it stands, the precise connection between the three ATR zones demarcated in Figure 18 is unsettled. There are a number of logical hypotheses. The most straightforward is that the distinct ATR zones developed from a single proto-language whose descendants then split into three linguistic groups. This is somewhat plausible for the Atlantic ATR zone and the West African Zone, as they are separated by the Guinean ATR-deficient zone, which mostly consists of single family, Mande. However, there is no convincing historical evidence showing genetic relations between the languages of the West African ATR zone (largely Niger-Congo) with the languages of the East African ATR zone (largely Nilo-Saharan). We refer to this hypothesis as 'ATR via vertical inheritance', but will not discuss it further in this paper.

Another reasonable hypothesis is that the distribution of ATR is due to language contact. Under this hypothesis, ATR emerged in a population and spread to genetically unrelated populations that they were in contact with. This model entails that at one point, the ATR zones (or the populations within these zones) were not separated. Their later separation might then be due to linguistic changes in the languages between the modern day ATR zones, e.g. due to the arrival of new languages with a different profile. A plausible candidate for the lack of ATR in the Guinean ATR-deficient zone is the Mande family, and the arrival of Chadic family in the Central African ATR-deficient zone. One important aspect of this hypothesis to investigate would be whether incomplete harmony systems between the complete ATR zones (the Mande family in the west and the Gbaya family in the east) realistically form an 'areal bridge'.

A third more tenuous hypothesis is that ATR developed independently in two or all three of these ATR zones. This hypothesis is complicated by the fact that ATR systems are exceptional outside of Africa, constituting what Güldemann (2010:113) calls 'cross-linguistic quirks' (citing Gensler 2003). However, as mentioned throughout this study the West African and East African ATR zones have distinct internal profiles, such as the distribution of 5Ht[H] being found only in the West (lacking phonemic [-ATR] /ɪ ʊ/) and 5Ht[M] only in the East (lacking phonemic [+ATR] /e o/) (for definitions of these codes, refer to Table 2 in section 3.1 above). More research is required, especially in how ATR harmony is implemented articulatorily across these three ATR zones.

Related to this line of inquiry, the diachronic relationship between ATR and interiority requires substantial further diachronic investigation. We sketch several plausible historical developments in example (6) below. The first hypothesis is 'loss-before-gain', in which either ATR or interiority is lost first, then only later does the other develop (analogous to a 'pull chain'). The second is 'gain-before-loss', in which both an ATR system gains interior vowels or an interior system gains ATR and the two therefore co-exist at some intermediate diachronic stage (as in the systems in Table 7-Table 9 in section 5.1 above). Only at a later third stage is the original property lost. Finally, another possibility is a direct change from an ATR contrast with harmony to an interior contrast without harmony, or vice versa.

6. Plausible diachronic pathways

a. Loss-before-gain	Stage 1	Stage 2	Stage 3
ATR loss before interior gain	/i ɪ u ʊ/	/i u/	/i ɨ u/
Interior loss before ATR gain	/i ɨ u/	/i u/	/i ɪ u ʊ/
b. Gain-before-loss	Stage 1	Stage 2	Stage 3
ATR gain before interior loss	/i ɨ u/	/i ɪ ɨ ɘ u ʊ/	/i ɪ u ʊ/
Interior gain before ATR loss	/i ɪ u ʊ/	/i ɪ ɨ ɘ u ʊ/	/i ɨ u/
c. Direct	Stage 1	Stage 2	
ATR directly to interior	/i ɪ u ʊ/	/i ɨ u ʉ/	
Interior directly to ATR	/i ɨ u ʉ/	/i ɪ u ʊ/	

Each of these three idealized scenarios can be assessed for the languages of the Macro-Sudan Belt.

There is some evidence that ATR harmony can be reconstructed for at least the more embedded branches of Niger-Congo, e.g. within families Edoid (Elugbe 1989), Kwa (Snider 1989) and Gur (Rennison 1992). However, even here there are complications. For example, Snider (1989:30) reconstructs Proto-Guang (a family within Kwa) as having both ATR distinctions and interior vowel allophones of proto-phonemes. For example, [+ATR] *ɨ *ə and [-ATR] *ᵻ *ʌ are reconstructed as allophonic variants of front vowel counterparts, e.g. Proto-Guang */ki-tiŋ/ *[kɨ-tɨŋ] 'piece' > Gonja [kɨ-ʃiŋ], Chumburung [kɨ-tɨŋ], and Gichode [gᵻ-dᵻŋ].

Finally, one promising topic is the role [-ATR] high vowels play in these diachronic scenarios. Such vowels are perceptually weaker and therefore may trigger harmonic processes to 'support' them, as discussed in Rose (2018:7; see Rose, and Casali 2003:342 for references). One strategy to increase perceptual distinctness is centralization.

6.3 Central Africa as a linguistic area

One clear result from our survey is supporting Central Africa as a linguistic area. The presence of interiority and the lack of ATR corroborates other areal features not found in other parts of the Macro-Sudan Belt or in other regions of Africa. Other features include the presence of the labial flap [ⱱ] (Olson & Hajek 2003, Anonby 2007, Güldemann 2008:169), S-V-O-NEG word order (Dryer 2009), and minimal-augmented pronoun systems (Güldemann 2008:169-171). Maps showing the first two features are provided below from their original sources.

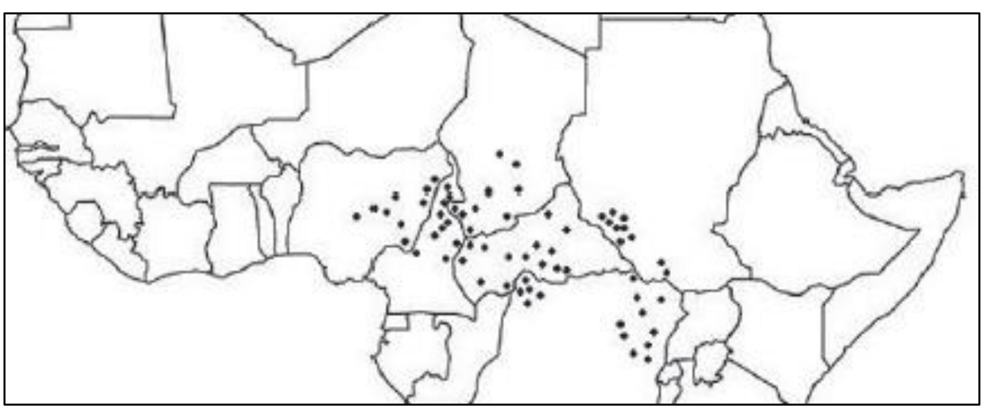

Figure 19: Distribution of the labial flap in Africa (Anonby 2007:3)

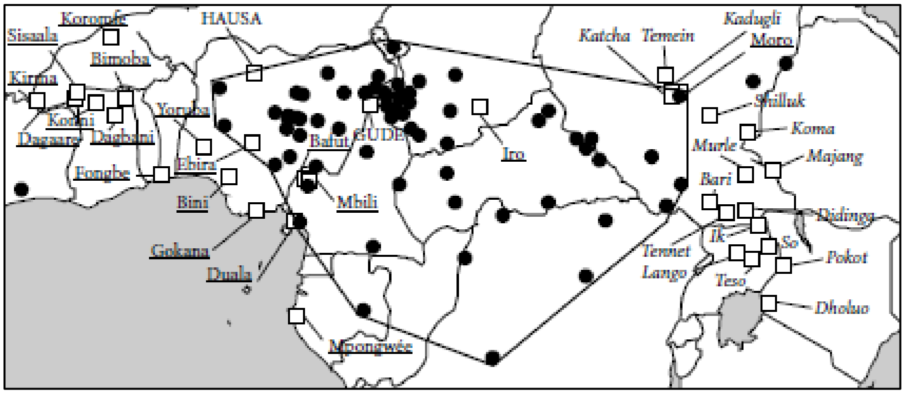

Figure 20: Order of verb and negative among VO languages in Central Africa (Dryer 2009:323) (black circle are VO languages with V-Neg order, dilineated with solid line; white squares are VO languages with Neg-V order)

Further inquiry can show how well these separate isoglosses line up and whether there are additional linguistic features defining Central Africa as a linguistic area.

6.4 Historical correlates and linguistic diachrony

To conclude, one of the central challenges for assessing macro-areas such as the Macro-Sudan Belt hypothesis is that unlike traditional sprachbunds, macro-areas in general have either limited contract scenarios or no plausible contact scenario (Muysken 2008:5). Just as with assessing genetic phyla, the time depth for macro-areas is quite deep, with ample opportunity for several cycles of language change to reconfigure linguistic profiles.

The linguistic zones in Figure 18 above (e.g. the West African ATR zone) can be classified as linguistic 'meso-areas' using Muysken's terms, a classification above traditional sprachbunds but below largescale macro-areas. It would thus be ideal if these meso-zones received treatment with respect to their historical development in earnest, followed by assessment of how they fit together to form a macro-area. For example, in Central Africa what was the role of incoming Chadic languages in shaping non-Chadic languages (a question asked by Güldemann 2008:170), especially with regard to the prominence of interiority this area displays? Does the distribution of Adamawa languages suggest an older lineage in the area? Moving south, were features of the Macro-Sudan Belt more widespread prior to the Bantu expansion? And cutting across these topics, did linguistic features primarily spread latitudinally, predicted by Güldemann & Hammarström (2013) and suggested by the shape of the Macro-Sudan Belt and its natural geographical boundaries (the Sahara to the north and the ocean/rain forest to the south), or primarily longitudinally?

One language family in particular which is fruitful is Central Sudanic, traditionally placed in the Nilo-Saharan phylum. Of the genetic groupings we surveyed, Central Sudanic languages were the second most numerous (*n*=40), coming only after Bantu (*n*=69) (see Table 1 in section 2.2). Central Sudanic shows considerable internal typological diversity. For example, with respect to ATR our survey showed an even division between complete ATR (*n*=19) and no ATR systems (*n*=19). Similarity, for interiority there was a fairly even distribution for phonemic interior vowels (*n*=7), non-phonemic (*n*=14), the only interior being /ə/ as [+ATR,+low] (*n*=8), and no interior phones reported at all (*n*=11).

Proto Central-Sudanic was probably spoken near the DRC/Uganda/South-Sudan confluence (Ehret 1974, Boyeldieu 2006, 2009 a.o.), which places it in the present-day East African ATR zone. One branch within Central-Sudanic is the Sara-Bongo-Bagirmi (SBB) family. Proto Sara-Bongo-Bagirmi (SBB) was probably spoken around the same area between South Sudan and the

Central African Republic, and from there SBB speakers migrated westward outside of the East ATR zone and into the Central African interior vowel zone in southern Chad and northern Central African Republic (Boyeldieu 2006, 2009). A map of proposed SBB migrations is shown below in Figure 21, repeated from Boyeldieu (2006).

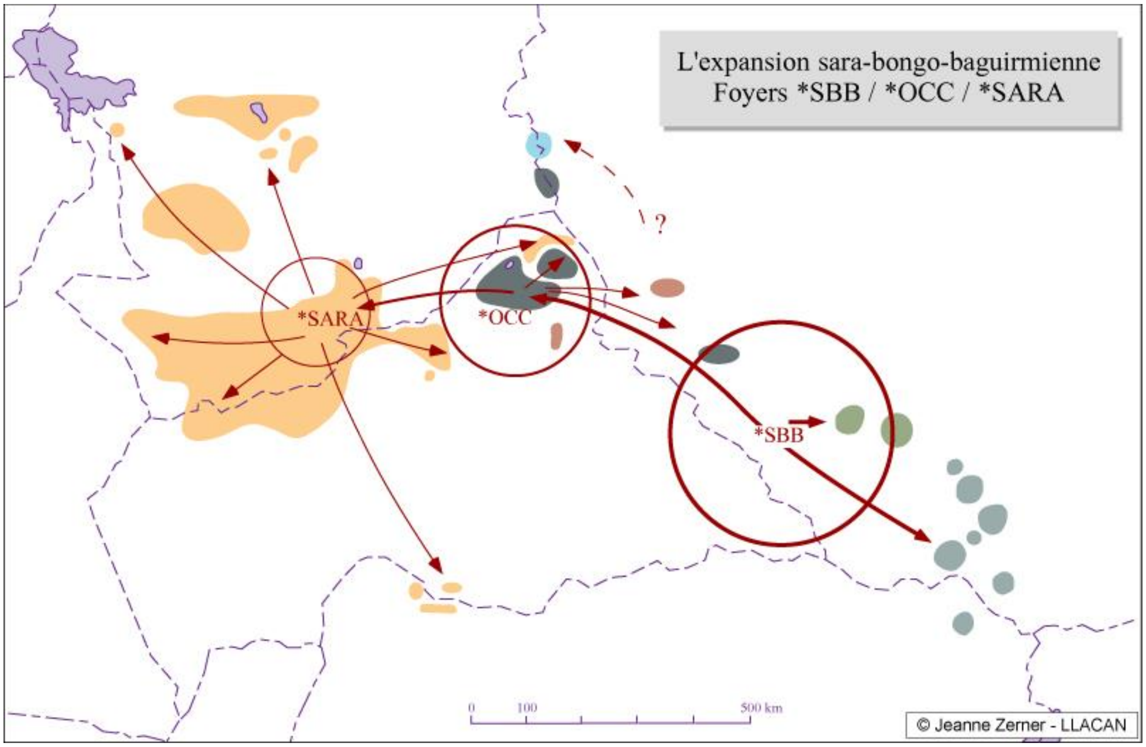

Figure 21: Migrations of Sara-Bongo-Bagirmi (SBB - Boyeldieu 2006)

Those Central Sudanic and SBB languages still spoken in the East ATR zone have ATR harmony. However, SBB languages which moved west into the Central African interior vowel zone do not have ATR distinctions, and rather have developed interior vowels, e.g. all Sara languages except the Sara Kaba subgroup which is also the easternmost (Keegan 1995, 2013).[11] This is very suggestive of a scenario in which SBB languages adapted their phonological profile to the new area they were entering (i.e. lost their ATR contrast and harmony and gained interior vowels).

On the other side of the Central African interior vowel zone, the distribution and phonological profiles of Adamawa languages is also particularly revealing.[12] Indeed, Adamawa languages with full ATR harmony are attested in only two areas: the West African ATR zone (e.g. Waja-Tula, Burak-Loo, Longuda in Nigeria - Kleinewillinghöfer 2006: 28), and an area that

[11] Boyeldieu (2006, a.o.) remains agnostic as to whether proto-SBB is to be reconstructed with ATR, but does not consider it an unlikely hypothesis (p.c.).

[12] It is unclear whether "Adamawa" is a valid genetic unit. That these languages are all Niger-Congo is widely accepted, but the exact classification of the family and the relations between Adamawa subgroups with other Niger-Congo families (e.g. Gur or Ubangi) are still unclear (see Bennett and Sterk 1977, Bennett 1983, Kleinewillinghöfer 1996, a.o.). We use the label "Adamawa" out of mere convenience here, without speculating about the exact genealogical status of this grouping. "Proto-Adamawa" is meant to refer to the language that all present-day Adamawa languages descend from, whether the descendants of this proto-language are only Adamawa, or a wider set of languages including, for example, some or all Gur or Ubangi languages.

is intermediate between the Central African interior vowel zone and the East African ATR zone (Inland Bua languages in south-central Chad; Boyeldieu et al. forth.). It is likely that ATR harmony is to be reconstructed for proto-Adamawa. It is attested or tentatively reconstructed in several non-contiguous Adamawa subgroups, e.g. Waja-Tula, Burak-Loo, Longuda (Kleinewillinghöfer 2006: 28) in Nigeria, proto-Kebi-Benue (Elders 2006:55-57) in the Cameroon/Chad borderland, and Proto-Bua (Boyeldieu *et al*. forthcoming) in southeastern Chad.

All the Adamawa languages spoken in between these two areas fall within the Central African interior vowel zone. None of them has ATR harmony but many have interior vowels, at least phonetically (Mumuye, Samba-Leko, Mom Jango, Kolbila, Ndai, Bena, Mundang, Day, and Riverine Bua languages). Mundang, spoken across the border between Cameroon and Chad, i.e. in the Central African interior vowel zone, is particularly interesting, in that it has both allophonic interior vowels as well as clear traces of a former full ATR harmony system that has lost its regularity and is in the process of breaking down (Elders 2000:55-60). If ATR harmony is indeed an old Adamawa feature (possibly inherited from an even older Niger-Congo ancestor), then the distribution of vowel profiles in the Adamawa spread zone described above seems to suggest that the Adamawa languages spoken in the core of the Central African interior vowel zone may have lost the ATR contrast, and started developing interior vowels.

While it seems possible in certain well-documented cases (e.g. Central Sudanic noted above) to trace the historical adaptation of particular languages or language families to specific areal profiles, in most cases it is not yet feasible to determine the relative age of these areal zones or their origin. This discussion points to the need for increased exchange between synchronic phonological analysis, diachronic linguistics, and African history.

7 Correspondence addresses

…[to be completed upon acceptance]…

8 Acknowledgments

…[to be completed upon acceptance]…

9 Appendix

		ATR			Interiority			
Family	*n*	Complete	Incomplete	No	Phonemic	Non-phonemic	[+ATR,+low]	None
Bantu	69	20	23	26	11	4	6	48
Central Sudanic	40	19	2	19	7	14	8	11
Atlantic	31	14	3	14	9	2	12	8
Other NS	29	14	2	13	8	4	5	12
Adamawa	26	2	6	18	13	3	0	10
Potou-Tano	26	21	3	2	3	2	4	17
Nilotic	25	19	5	1	7	1	7	10
Central Gur	23	12	2	9	3	5	1	14
Edoid	22	10	0	12	0	0	3	19
Grassfields	21	0	0	21	19	2	0	0
Ubangi	21	3	8	10	9	2	3	7
West Chadic	18	1	0	17	12	3	0	3
Other Kwa	17	8	7	2	3	3	1	10
Platoid	17	2	4	11	6	4	1	6

		ATR			Interiority			
Family	*n*	Complete	Incomplete	No	Phonemic	Non-phonemic	[+ATR,+low]	None
West Mande	17	0	12	5	3	2	0	12
South Gur	16	14	1	1	2	3	6	5
Biu-Mandara	15	0	0	15	12	3	0	0
Kainji	15	0	2	13	12	1	0	2
East Mande	14	3	5	6	2	0	1	11
Gbaya	13	0	12	1	0	1	0	12
Other Bantoid	13	1	0	12	10	1	0	2
NC-Kordofanian	12	6	1	5	11	0	1	0
Other AA	12	2	0	10	6	1	1	4
Delta-Cross	11	5	5	1	1	0	4	6
East Chadic	10	0	1	9	3	1	0	6
Ijoid	10	8	2	0	0	0	0	10
Jukunoid	10	1	0	9	6	0	0	4
Omotic	9	0	0	9	1	3	0	5
Dogon	9	1	8	0	0	1	1	7
Gbe	9	0	0	9	3	0	0	6
Surmic	9	4	0	5	0	2	1	6
North Bantoid	8	0	2	6	7	1	0	0
Igboid	7	7	0	0	0	2	0	5
Other Gur	7	4	1	2	0	1	0	6
Senoufo	7	0	3	4	1	4	0	2
West Kru	7	2	5	0	0	0	0	7
Songhai	7	0	2	5	1	0	0	6
Defoid	6	3	3	0	0	0	0	6
Idomoid	6	1	4	1	1	0	1	4
Creole	6	0	1	5	1	2	0	3
Other NC	5	1	3	1	1	0	0	4
Nupoid	5	2	0	3	0	2	1	2
South Atlantic	5	0	1	4	2	0	0	3
Maban	5	0	1	4	2	2	0	1
East Kru	4	4	0	0	2	0	0	2
Saharan	4	3	0	1	2	1	1	0
Other	3	0	2	1	2	0	0	1
TOTAL	681	217	142	322	204	83	69	325

Table 15: Families by ATR and Interiority value
Niger-Congo (NC - *n*=487), Nilo-Saharan (NS - *n*=119), Afroasiatic (AA - *n*=66), Other (*n*=9)

Language	ISO	Interior allophony	Genetic group	Source
Mambila	mcu	/u/ > [y] /e/ > [ə]	Bantoid	Perrin (1987 [2005]), Connell (2007)
Noni	nhu	/e/ > [ə] /ɛ/ > [ʌ]	Grassfields Bantoid	Hyman (1981)
Njebi	nzb	/V/ > [ə]	Bantu	Blanchon (1999)
Boma	boh	/a/, /ɔ/, /ɛ/ > [ə] /_ r	Bantu	Stappers (1989)
Amo	amo	/i/ > [ɨ] / ._C. /u/ > [ʉ] / ._C.	Kainji, Benue-Congo	Di Luzio (1972/1973)
Bo-Rukul Fyem Horom	mae pym hoe	/i/ > [ɨ] / ._C.	Platoid, Benue-Congo	Nettle (1998)
Waja	wja	/i/, /u/ ([+ATR]) > [ə] / /ɪ/, /ʊ/ ([-ATR]) > [ɜ] /	Adamawa	Kleinewillinghoefer (1991)
Mumuye	mzm	/i/ > [ɨ]	Adamawa	Shimizu (1983:1-24)
Tunia	tug	/V/ > [ɨ~ʉ~ə]	Adamawa	Palayer (1975)
Northwest Gbaya	gya	/u/ > [y] /o/ > [ø] /ɛ/ > [œ]	Gbaya	Monino (1995:58-68)
Sar	mwm	/V/ > [ɨ]	Sara, Central Sudanic	Palayer (1989:22-88; 1992:14-19); Keegan (2013:10)
Kenga	kyq	/V/ > [ə]	Sara, Central Sudanic	Neukom (2010:25-29; 40-43), Palayer (2004:9-10)
Mbay	myb	/V/ > [ɨ] /e/ > [ə]	Sara, Central Sudanic	Caprile (1977); Keegan (1997:4-9); Djarangar (1991)
Bedjond Gor	bjv gqr	/e/ > [ə] / ._C$_{[+son]}$.	Sara, Central Sudanic	Keegan (2012)
Ngambay	sba	/e/, /o/ > [ə]	Sara, Central Sudanic	Keegan (2013)
Ngiti	niy	/o/ > [ə]	Central Sudanic	Kutsch-Lojenga (1994)
Dazaga	dzg	/V/ > [ɨ]	Saharan	Walters (2015:24-38)
Afitti	aft	/i/ > [ɨ] / ._C.	Eastern Sudanic(?)	Voogt (2009)
Hausa	hau	/i/ > [ɨ] / ._n. /u/ > [ʉ] / ._n.	West Chadic	Salim (1977: 133)
Pero	pip	/i/, /u/ > [ɨ]	West Chadic	Frajzyngier (1989:28-53)
Dangaleat	daa	/i/, /u/ > [ə]	East Chadic	Ebobissé (1979:15-18,24-25); Fédry (1977)

Table 16: Sample of languages in or near Central African interior vowel zone which only have allophonic interior vowels

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