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**Areal patterns in the vowel systems
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Abstract: This paper investigates the areal distribution of vowel systems in the Macro-Sudan Belt, an area encompassing most of the western and central parts of northern Sub-Saharan Africa. 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 [i u 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 zone, a West African zone, and an East African zone. Between the West and East African ATR Zones is a genetically heterogeneous region where ATR harmony is systematically absent: we term this 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; this finding is supported through statistical tests. Second, our survey supports the existence of the Macro-Sudan Belt, but the discontinuous distribution of ATR harmony and its systematic absence in Central Africa challenges the proposal that this area represents the ‘hotbed’ of the Macro-Sudan Belt.

Keywords: phonology, vowel systems, vowel harmony, advanced tongue root, macro-areas, areal typology, Macro-Sudan Belt, Africa

1 Introduction

There has been a recent resurgence in Africanist linguistics towards areal explanations of shared linguistic features, rather than genetic explanations

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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, Güldemann 2010, Güldemann 2011, Güldemann 2018b), 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 (advanced tongue root [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 common linguistic features across languages whose relationship 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 regions over which linguistic features spread more easily compared to spreading into other regions, and therefore do not entail that all features are equally distributed in the macro-area or that even a majority of languages in the area 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 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 large-scale database called Areal Linguistic Features of Africa (ALFA), a copy of which is included in the supplementary materials. ALFA contains information on the vowel systems of 681 language varieties from every major subgroup within the Macro-Sudan Belt, forming 47 sub-groupings in total, and is the largest database of its kind. An advantage of ALFA is that it encodes 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 which further refine our understanding of the Macro-Sudan Belt. First, we show that there are five phonological ‘zones’ within the Belt, within which languages converge on a specific vowel inventory profile. This is shown below in Figure 1.

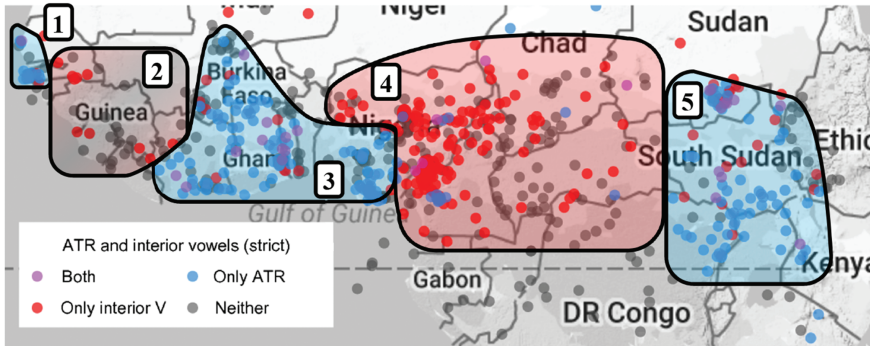


Figure 1: Five areal zones defined by vocalic systems in the Macro-Sudan Belt: [1] Atlantic ATR zone, [2] Guinean ATR-deficient zone, [3] West African ATR zone, [4] Central African ATR-deficient zone (includes Central African interior vowel zone), [5] East African ATR zone.

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 nearly 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 i 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 connecting Chadic languages in Chad and Northern Nigeria/Cameroon to the Niger-Congo families Bantoid and Delta-Cross towards the south, adding to the growing body of data showing that Central Africa is a linguistic area in its own right (see Section 6.2 below).

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 Macro-Sudan Belt to date, based on our extensive database. Second, this paper demonstrates that ATR and interiority are not independent from one another in the Macro-Sudan Belt, 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 in the following way: 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, previously proposed on the basis of smaller samples of languages. However, because ATR is systematically absent in Central Africa, this potentially complicates the notion that it is the ‘hotbed’ of the Macro-Sudan Belt (Güldemann 2008: 167, Güldemann 2010: 572). 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 generally ‘lumpers’ rather than ‘splitters’ (cf. Campbell 2003: 34–35 for terminology), and have long explicitly or implicitly adopted pre-existing genetic classifications such as Greenberg’s (1963) four phyla Afroasiatic, Niger-Congo, Nilo-Saharan, and until recently ‘Khoisan’. Of these, 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

relationship is apparent (e.g. Bantoid in Niger-Congo, Nilotic in Nilo-Saharan, among others) 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 2018a). These hypotheses have been highly valuable in generating decades of comparative work and sharpening the evidence for families within these stocks 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), who 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 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 and 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.

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

The recent resurgence of areal-typological research in this century has furthered our knowledge. This includes areal-typological volumes on West and Central Africa (Zima 2000, Zima 2009; Comrie & Wolff 2004; Caron & Zima 2006) as well as pan-African edited volumes (Sauzet & 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 (Güldemann 2003: 384–385; Cyffer et al. 2009; Idiatov 2018) and phonological features (Clements & Rialland 2008; Güldemann 2008, Güldemann 2010, Güldemann 2018b; Idiatov & Van de Velde 2016).

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 and Rialland (2008) divide the continent into six macro-areas, largely horizontal bands stretching east-west (Figure 2). In prior and independent work, Güldemann (2003, 2008, 2010) proposes a similar division of the continent

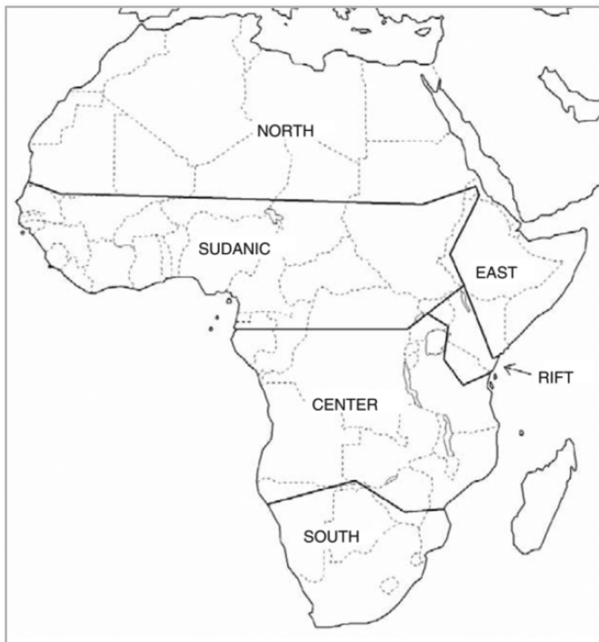


Figure 2: Macro-areas of Africa (Clements & Rialland 2008: 37).

into 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, e.g. the Macro-Sudan Belt contains languages from Niger-Congo, Nilo-Saharan, and Afroasiatic (as well as several isolates).

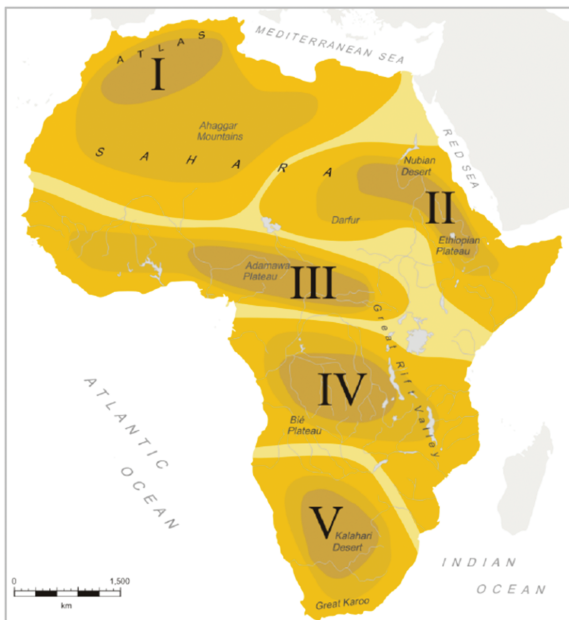


Figure 3: Macro-areas of Africa (Güldemann 2010: 2911).

Güldemann (2018b) proposes an updated version of his (2008, 2010) initial proposal, the most important changes being the inclusion of Arabia in the ‘Sahara spread zone’, renamed ‘Afroasiatic spread zone,’ the identification of a ‘Central transition sphere’ including both a Sahel transition zone (IVa) between the Macro-Sudan Belt and the Afroasiatic spread zone to the north, and an East Sudan-Gregory Rift transition zone (IVb) between the Macro-Sudan Belt and the Chad-Ethiopia area to the east. We will come back to more specific modifications proposed by Güldemann (2018b) in Section 6.

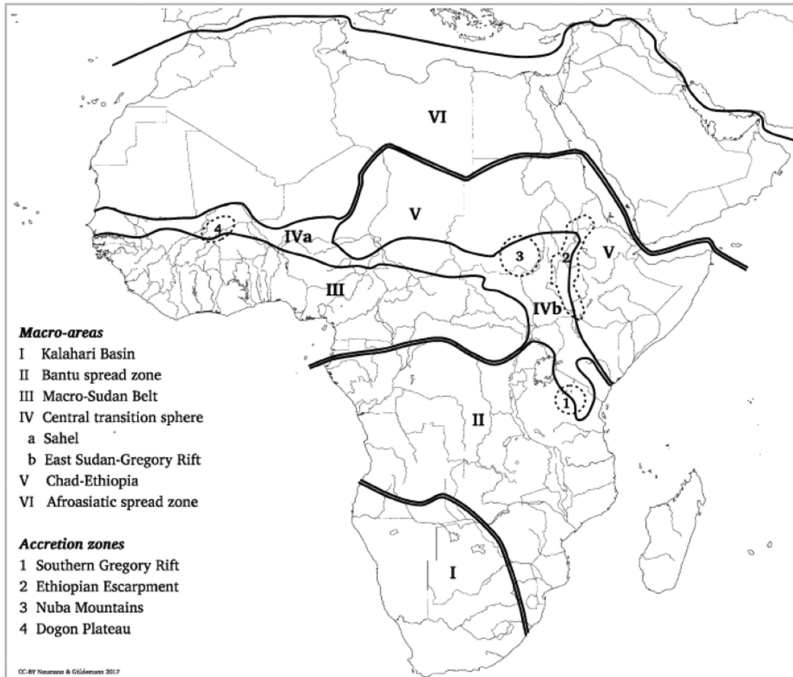


Figure 4: Macro-areas and accretion zones of Afrabia (Güldemann 2018b: 473).

These maps illustrate that Clements & Rialland’s ‘Sudanic Belt’ and Güldemann’s (2003, 2008, 2010, 2018b) ‘Macro-Sudan Belt’ are largely coextensive, and converge on an area encompassing most of the western and central parts of northern Sub-Saharan Africa. One major difference between the two proposals is in the northern and eastern ‘borders’ of the Macro-Sudan/Sudanic Belt, considered transition zones by Güldemann (2018b), as mentioned above, but included in the Sudanic Belt by Clements & Rialland. Although Clements & Rialland (2008: 67–68) do not define these transition zones as such, they do recognize their ambivalence toward the features defining their Sudanic Belt, recognizing in particular that what Güldemann (2018b) now terms the East Sudan-Gregory Rift transition zone “tends to lack the characteristic Sudanic features.” They conclude, following Schadeberg (1987) that “on the basis of these characteristics, the eastern Sudan might merit consideration as a zone of its own,” but add that since “two characteristic Sudanic features are found to its east, implosives and multiple tone heights,” one may wonder “whether the Sudanic belt as defined here might not have been linguistically more homogeneous in the past.”

The features defining the Macro-Sudan Belt differ from author to author, as shown in Table 1. They converge on a core set of phonological properties: labial-velar stops, implosives, nasal vowels, ATR-harmony (replaced by 7+vowel systems in Güldemann 2018b, which we will discuss in Section 6), 3+tone heights, and ‘lax’ question prosody. Clements and Rialland (2008) were exclusively concerned with phonological features. Partly based on previous typological studies, Güldemann (2003, 2008, 2018b) additionally includes several morphosyntactic features: logophoricity, Object-Verb-Other word order, Post-verbal/clause-final negation, ‘(sur)pass’ comparatives, split predict/STAMP morpheme,² plural word, and locative-existential conflation.

Table 1: Features defining the Macro-Sudan/Sudanic Belt, according to Clements and Rialland (2008), Güldemann (2008, 2010), and Güldemann (2018b).

Feature	Clements and Rialland (2008)	Güldemann (2008, 2010)	Güldemann (2018b)
Phonological features			
<i>Labial flap</i>	yes	yes	–
<i>Labial-velar stops</i>	yes	yes	yes
<i>Implosives</i>	yes	–	yes
<i>Nasal vowels</i>	yes	–	yes
<i>Vowel ATR harmony system</i>	yes	yes	–
<i>7+vowel qualities</i>	–	–	yes
<i>3+tone heights</i>	yes	yes	yes
<i>‘Lax’ question prosody</i>	yes	–	yes
Morphosyntactic features			
<i>Logophoricity</i>	–	yes	yes
<i>OBJ-V-OTHER word order</i>	–	yes (S-AUX-O-V-X)	yes
<i>Post-V/Clause-final negation</i>	–	yes	yes
<i>‘(Sur)pass’ comparative</i>	–	–	yes
<i>Split predicate/STAMP morph</i>	–	–	yes
<i>Plural word</i>	–	–	yes
<i>Locative-existential conflation</i>	–	–	yes

Güldemann (2008, 2010, 2018b) goes further than Clements & Rialland in that he does not only delineate his Macro-Sudan Belt, but also gives a tentative hypothesis regarding its internal structure. Indeed, we can see in Figure 3 that the Macro-Sudan Belt is split into three concentric ovoid shapes distinguishing the core and

² STAMP stands for subject/tense/aspect/mood/polarity (Anderson 2017).

peripheral areas, with a ‘hotbed’ core in the center of the macro-area (Güldemann 2008: 168), in brown in Figure 3. This structure is not visible in Figure 4, taken from Güldemann (2018b), but is still assumed by the author in his description of the Macro-Sudan Belt (p. 572). 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 now turn to these efforts.

2.2 A database of vowel systems in Africa

As stated, this paper examines the distribution of two phonological features within the Macro-Sudan Belt macro-area: advanced tongue root (ATR) harmony (characteristic of the macro-area according to Clements & Rialland 2008; Güldemann 2008, Güldemann 2010), and the presence of interior vowels, which we show is areal in the central part of the Macro-Sudan Belt. To this end, we have constructed a database of vowel systems in Africa, part of a larger project started at the University of California, Berkeley 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 are available, and we include these languages if we consider the resources to be 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), among others.

Our survey included languages from all major families in the three major Greenbergian stocks present in 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 affiliation. For example, we surveyed 69 Bantu languages but 5 South Atlantic languages. The total number from each language grouping is shown below in Table 2.

The map in Figure 5 shows the locations of language varieties contained in the current survey, split up by Greenbergian stock. Figure 5 and all other maps throughout this paper were created using the ggmap package in R (Kahle & Wickham 2013).

Table 2: Languages surveyed from each Greenbergian stocks within Macro-Sudan Belt ($n = 681$), Niger-Congo (NC – $n = 487$), Nilo-Saharan (NS – $n = 119$), Afroasiatic (AA – $n = 66$), Creole & other ($n = 9$).

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

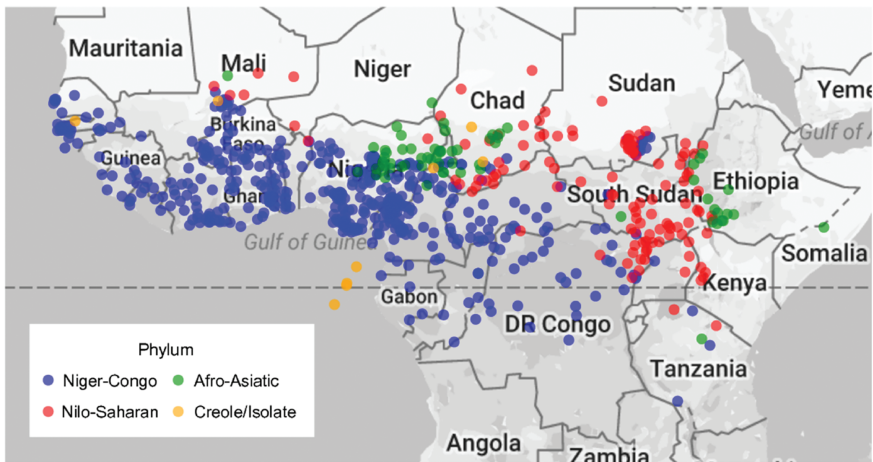


Figure 5: Map of language varieties in the ALFA database ($n = 681$).

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). By exhaustively encoding both phonemic and allophonic information on vowel qualities, we are 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 copy of this database is provided in our supplemental materials, as well as the references 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 their typological and phonological properties (Stewart 1967, Stewart 1971; Hall et al. 1973; Williamson 1983; Blench 1995: 89–91; Baković 2000; Dimmendaal 2001; Casali 2003, Casali 2008, Casali 2016; Güldemann 2008; Clements & Rialland 2008, among others) 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 using a phone with 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.

Idiatov (2009: 1394–1395) notes that the feature [±ATR] has a history of being used very liberally in the analysis of African vowel systems, with often no phonetic evidence that tongue root position is indeed involved, and sometimes with no phonological evidence of cross-height harmony to necessitate the use of a non-height-related feature such as [ATR]. For the purposes of our survey, we abstract away from the phonetic implementation of ATR and concentrate on phonological behavior, namely cross-height harmony.

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]
/i̩ e̩ a̩ o̩ u̩/ (~ /i e ɜ o u/)	/i̥ e̥ ḁ o̥ u̥/ ~ (/ɪ ɛ ə 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’	(*βune)
[-ATR]	ṃure	/ṃʊrɛ/	‘light (a fire)’	(*ṃʊrɛ)

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

[+ATR]	duw	/duw/	‘be soft’	duw-ese	[duwese]	‘cause to be soft’
[-ATR]	ṣɪn	/ṣɪn/	‘climb’	ṣɪn-ese	[sṃɛsɛ]	‘cause to climb’

We encode three types of ATR harmony system for the 681 languages in ALFA. Nearly half of the database ($n = 322$) exhibits 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 & Margaret 1973, Williamson & Margaret 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 ... ε] or *[ɔ ... i] occur. Note that the presence or absence of [+ATR] low vowel qualities, such as /ə/, /ɜ/, or /ɔ̄/, plays no role in this classification.

We specify three subtypes of Complete ATR systems, shown in Table 3. 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.

Table 3: Complete ATR types ($n = 217$).

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

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 is therefore not contrastive. Example b. in Table 3 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/.³ For example, the 5Ht[M] language Kakwa [keo] (Nilotic: South Sudan – Onziga & Gilley 2012) has an ATR harmony system with the phonemes /i ɪ e a ɔ ʊ u/, but

³ Note that the 5Ht[M] system corresponds to Casali’s (2003: 309) 4Ht(H) system.

no phonemes */e o/. A sample of words with identical vowels is provided in Table 4. However, when /ε ɔ/ appear in the context of [+ATR] /i u/, the former surface as [+ATR] variants [e o] respectively, e.g. /pírɛ́/ ‘fatten’ [pírɛ́] and /ɔ́pú/ ‘corpse’ [ɔ́pú].

Table 4: Example of 5Ht[M] complete ATR system in Kakwa.

/i/	/ɪ/	*/e/	/ε/	/a/	/ɔ/	*/o/	/ʊ/	/u/
pírɪ́	wírɪ́	–	léme	máta	mókɔ	–	mógó	pútú
‘place’	‘song’	–	‘grass type’	‘chief’	‘leg’	–	‘body’	‘dust’

Analogously, type c. in Table 3 illustrates the 5Ht[H] subtype of Complete ATR system, where /e ε o ɔ/ are contrastive phonemes, but [–ATR] [ɪ ʊ] are strictly allophones of [+ATR] /i u/ in the context of [–ATR] /ε ɔ/. These systems are common in Yoruba [yor] dialects such as Akure, Ijesa, Ekiti, and Ifaki (Capo 1985; Casali 2003: 325; Przedziecki 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 e₁ e₂ ε a ɔ o₂ o₁ u/ where both /e₁ e₂/ and /o₁ o₂/ map to the same phonetic vowel qualities [e] and [o], respectively, but are distinguished based on phonological behavior: /e₁ o₁/ trigger [–ATR] allomorphs of functional morphemes and act phonologically as high vowels (i.e. /ɪ ʊ/), whereas /e₂ o₂/ 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 ε (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 – Ali et al. 1998), the vowels /i/ and /ɪ/ are contrastive but may co-occur, e.g. compare /viði/ ‘cut hair’ vs. /ðixɪ/ ‘thorn’, with similar patterns for mid vowels (e.g. /oɾɛl/ ‘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 ε (ə) a ɔ o u/, lacking the [-ATR] high counterpart of /i u/ both as contrastive phonemes (*[i ʊ]) and as allophonic variants (*[i 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 /ε ɔ/ and vice versa, i.e. *[e... ε] and *[ɔ... o] in gray in Table 5 below.

Table 5: Mid height co-occurrence restrictions in mid harmony Incomplete ATR systems.

Sequences			Sequences		
✓	i...i	i...u	✓	u...i	u...u
✓	i...e	i...o	✓	u...e	u...o
✓	i...ε	i...ɔ	✓	u...ε	u...ɔ
✓	e...i	e...u	✓	o...i	o...u
✓	e...e	e...o	✓	o...e	o...o
*	e...ε	e...ɔ	*	o...ε	o...ɔ
✓	ε...i	ε...u	✓	ɔ...i	ɔ...u
*	ε...e	ε...o	*	ɔ...e	ɔ...o
✓	ε...ε	ε...ɔ	✓	ɔ...ε	ɔ...ɔ

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 ε o ɔ/ are. Compare the form of the reversive suffix /-ilɛ/ in /dèbè-îlé/ [dèbîlé] ‘get unstuck’ to /némbé-îlé/ [némbîlé] ‘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 /-ε/ do not alternate in the context of /e o/, e.g. [ǰ a yór-ε] ‘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 establishes, 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, among others). 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).⁴

We designate a smaller subtype of Incomplete ATR systems as ‘trace ATR systems’ (n = 20).⁵ 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 /-ni/: when attached to focus pronouns, it is realized [-ni] after high [+ATR] /i,u/, [-nè] after mid [+ATR] /e,o/, and [-nì] 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 contrast 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).⁶ 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 [nkx] (Obikudo 2008). Future work may be able to 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

⁴ 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.

⁵ Note that this is a more restricted definition of trace systems than we proposed in Rolle, Faytak, & Lionnet (2017: 6). In that paper, ‘trace’ referred to all types of Incomplete ATR systems.

⁶ An anonymous reviewer points out that while our discussion here is about “systems that are complete or not (i.e. phonology)”, the discussion of Dinka varieties focuses on phonetic realization. We maintain our classification of Dinka varieties as ‘Trace ATR’, but would also accept placing them as ‘No ATR’. We do not feel that this classification will impact our final conclusions, but it is a point worth exploring further (especially potential phonological restructuring due to shifted phonetic implementation across Dinka lects).

Incomplete ATR because they no longer have any clear vowel co-occurrence restrictions, e.g. the name Èdo /èdó/ ‘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 reconstructed 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 6). His survey reveals a West African

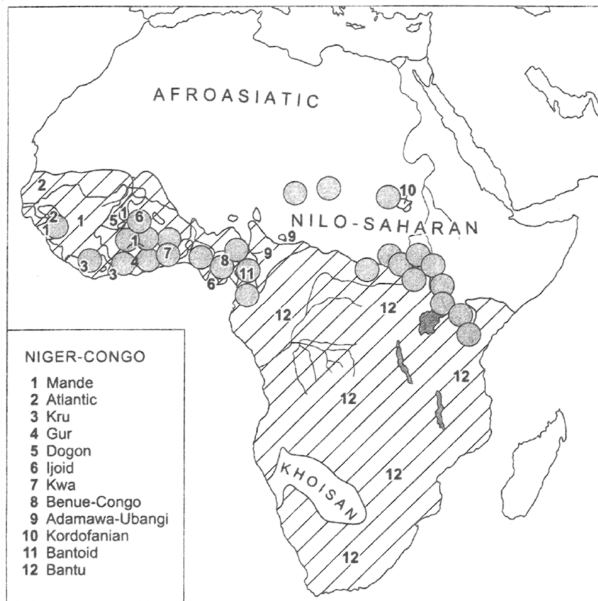


Figure 6: ATR languages (gray circles; Dimmendaal 2001: 370).

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.

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 Nilo-Saharan and Niger-Congo. 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 3) 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'.

Clements and 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 (in fact only southeastern 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 where ATR is *less* common, especially among Atlantic families, Gbe, Defoid (i.e. Yoruboid), Idomoid, Platoid, Jukunoid, Bantoid/Northwestern Bantu languages, and Adamawa-Ubangi (except Zandic). Moreover, they 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. In more recent work, Güldemann (2018b) does not consider ATR to be characteristic of the Macro-Sudan Belt, and replaces it with a more loosely defined '7+vowel qualities' criterion. We return to this new proposal in Section 6.

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

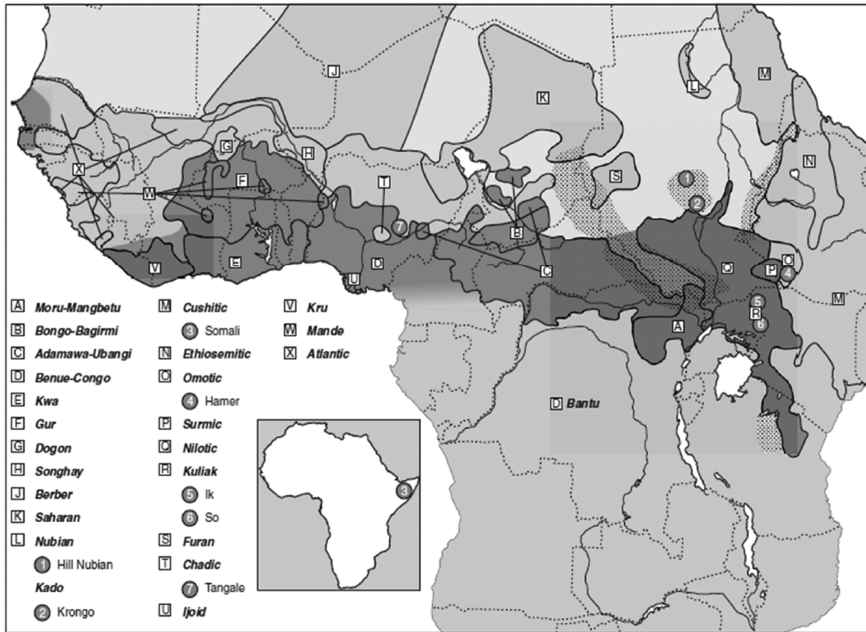


Figure 7: Distribution of ATR in dark gray (Güldemann 2008: 160).

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 8, illustrating a number of areal zones.⁷ 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 one, and consists of the

⁷ We use the neutral term ‘areal zone’ in the sense of Clements and Rialland (2008: 37), in order to avoid whether common features have spread through contact or genetic inheritance.

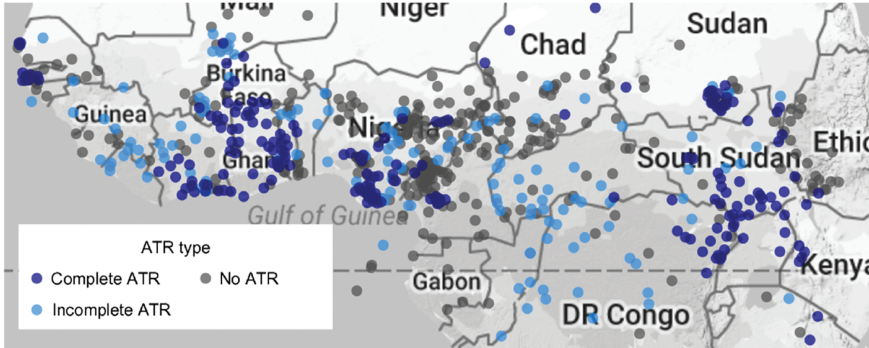


Figure 8: Areal distribution of ATR in our survey (Complete ATR ($n = 217$), Incomplete ATR ($n = 142$), No ATR ($n = 322$)).

small group of dark and light blue dots of North Atlantic languages in Senegal and the Gambia. This is the westernmost concentration of dark blue dots in the figure below. A table providing the breakdown of ATR type by language family is provided in Table 16 in the Appendix.

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 9, with several major languages noted as landmarks.

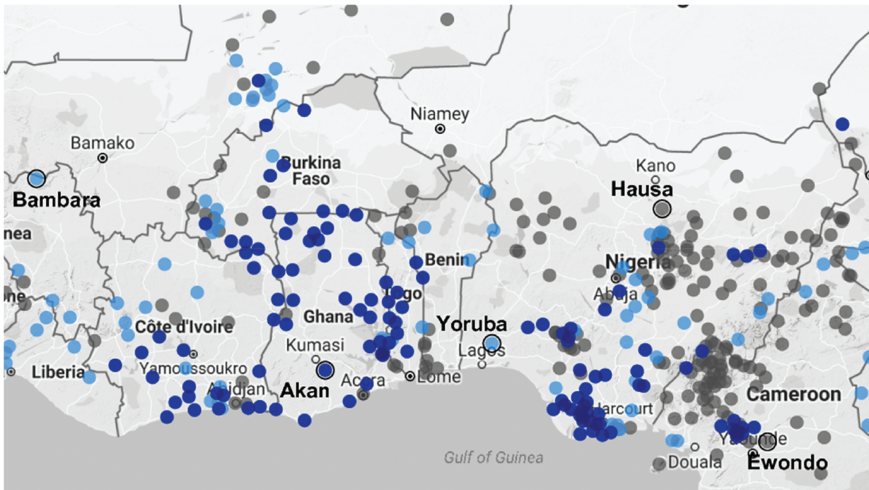


Figure 9: West African ATR zone (Complete = dark blue, Incomplete = light blue, No ATR = gray).

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 reason why we include this zone in the West African ATR zone is that it is relatively small (much smaller than the Guinean ATR deficient zone to the west, and the Central African ATR deficient zone to the east).

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 10 – an area that is largely congruent with Güdemann's (2018b) East Sudan-Gregory Rift transitional zone.

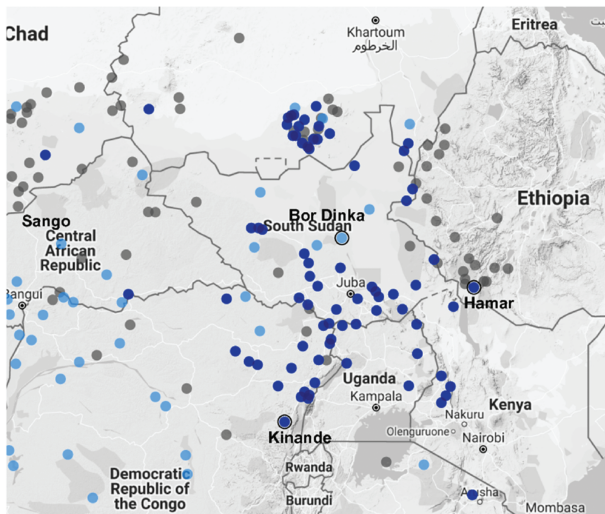


Figure 10: East African ATR zone (Complete = dark blue, Incomplete = light blue, No ATR = gray).

This zone is also genetically diverse, including languages from Kordofanian families (e.g. families Talodi-Heiban, Temein, among others), 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 gray in the bottom right of Figure 9. 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 8 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; however, see Kimper et al. (2019) for a critical re-examination based on new data). These outliers fall outside of the maps provided.

Our discussion of Complete ATR systems in Section 3.1 established three subtypes, provided in Table 3. 5Ht systems have phonemic ATR counterparts at both high and mid heights, 5Ht[M] systems have only [-ATR] / ϵ υ / phonemes but have [ATR] counterpart allophones [e ϵ o υ], and 5Ht[H] systems have only [+ATR] /i u/ phonemes but have [ATR] counterpart allophones [i ɪ u ʊ]. The map in Figure 11 below shows that the latter two systems are found in distinct zones.

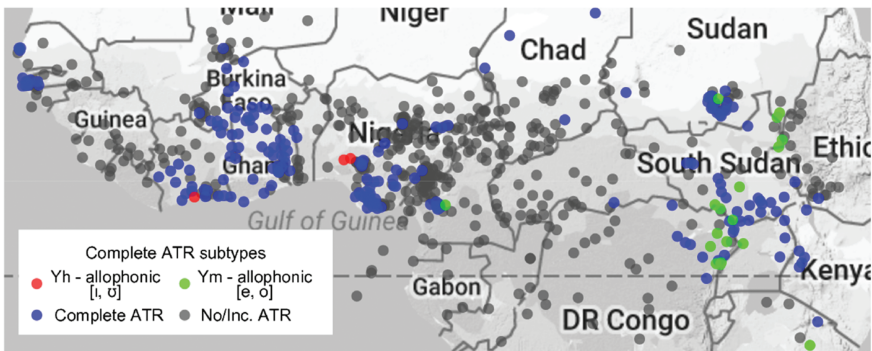


Figure 11: Distribution of complete ATR subtypes.

The blue dots represent Complete ATR 5Ht systems with a full set of high and mid phonemes. Red dots indicate 5Ht[H] languages without /i ʊ /, and occur entirely in the West African ATR zone and absent in East African (as previously

noted by Casali 2003: 362; 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 allophone of /ə/ and [o] is an allophone of /ʊ/, a situation quite distinct from [e o] allophony in East Africa (as described in Section 3.1).

Further, these figures (Figures 8–11) 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. 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 Figures 8 and 11.

The second is the Central African ATR-deficient zone, visible as the predominantly gray area between Chad and the Democratic Republic of Congo in Figures 8–11. 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. Another example is Mundang [mua] (Adamawa – Elders 2000), further east, which 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. These labels are meant to identify portions of the Macro-Sudan Belt that strikingly lack ATR-harmony. In total, 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 12 below.

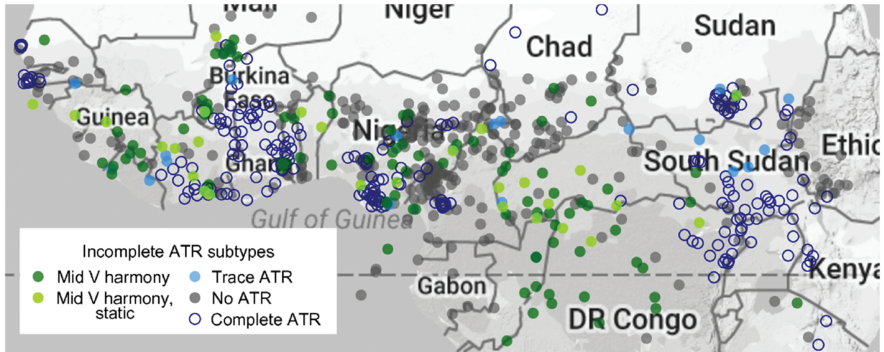


Figure 12: Incomplete ATR subtypes.

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 gray ($n=322$), 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.⁸ Vowel co-occurrence restrictions are especially prevalent

⁸ 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 – Lionnet 2017), Kera (Chadic: Chad – Pearce 2013: 85–87.), Iceve-Maci [bec] (Bantoid:

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. in the Adamawa language Kare [kbn] (Lim 1997: 95–98). Examples of typical co-occurrence restrictions outside of Adamawa/Ubangi are provided in Tables 6–7 below from Kaba [ksp]

Table 6: Agwara Kambari restrictions.

V2	i	u	ə	e	o	a
V1						
i	✓	✓	✓	✓	✓	✓
u	✓	✓	✓	✓	✓	✓
ə	✓	✓	✓	–	–	–
e	✓	✓	–	✓	–	–
o	✓	✓	–	–	✓	–
a	✓	✓	–	–	–	✓

Table 7: Kaba vowel co-occurrence restrictions.

V2	i	e	ɛ	a	ə	u	o	ɔ
V1								
i	✓	–	–	✓	–	–	✓	–
e	–	✓	–	–	–	–	✓	–
ɛ	–	–	✓	–	–	–	–	–
a	✓	–	✓	✓	✓	–	✓	✓
ə	–	–	–	–	✓	–	–	–
u	✓	✓	–	✓	–	✓	–	–
o	–	✓	–	–	–	–	✓	–
ɔ	✓	–	✓	–	–	✓	–	✓

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.

(Sara-Bongo-Bagirmi – Moser 2004: 40) and Agwara Kambari [asg] (Kainji – Stark 2000: 57; Nicholas Rolle & Geoff Bacon, field notes).

Kaba demonstrates a mid vowel co-occurrence restriction, but this restriction is part of a larger system restricting vowel co-occurrence generally. Agwara Kambari makes no contrast between mid vowels, but has a robust harmony system restricting non-high vowels /ə 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 have 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. We define interior vowels as those vowel qualities 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. This distinction is summarized in (3) below.

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

We opt to assess the presence of interior vowels rather than merely central vowels in order to group together high vowels /i ʉ u/ of different values for backness (and likewise mid vowels /ə ɜ ɤ ʌ/), thereby avoiding 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 /i/ as [i] or [u], 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 (/jəgə̀n/ ‘insult’ vs. /jīgə̀n/ ‘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. As an additional example, in Kejom [bbk] (Grassfields: Cameroon – Akumbu & Fogwe 2012), three interior phonemes /i ɤ ə/ contrast, found in the following minimal set:

4. Kejom minimal set for interior vowels /i ɤ ə/ and peripheral vowels /i e u o/
 /i/ tʃî ‘in-law’ /i/ tʃí ‘fireplace’ /ɤ/ tʃá ‘spit’ /u/ kə̀ntʃü ‘wild cat sp.’
 /e/ tʃê ‘minimize’ /ə/ tʃə ‘kick’ /o/ tʃō ‘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 (i.e. excluding Chadic). We show their map of interiority in Central Africa in Figure 13 below. The regions in pink are those areas they designated as having interior vowels.

Although Thomas et al. limit their survey to the Niger-Congo and Nilo-Saharan, 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, 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 [i] in closed syllables in Horom [hoe] (Platoid: Nigeria – Nettle 1998), which otherwise does not exhibit interior

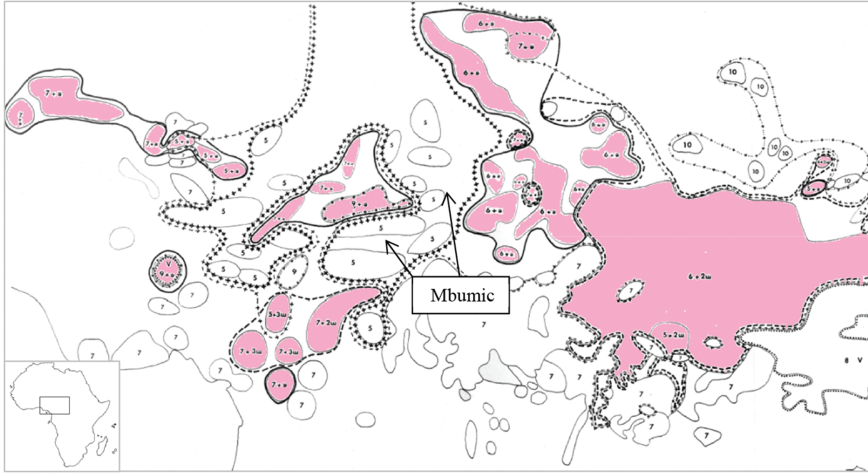


Figure 13: Map of interior vowels in Niger-Congo and Nilo-Saharan – Thomas et al. (1973: 136). Codes for interior vowels map (Thomas et al. 1973):

- +++++ 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

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 epenthetic vowels.

Our survey distinguished between two roles for the mid interior vowel (e.g. /ə/ or /ɜ/). One type is a [+ATR] vowel often represented as /ā/ but often just /ə/ (or /e/, /ɛ/, etc.). 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 /a/. 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.⁹

⁹ 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

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 14. 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 16 in the Appendix.

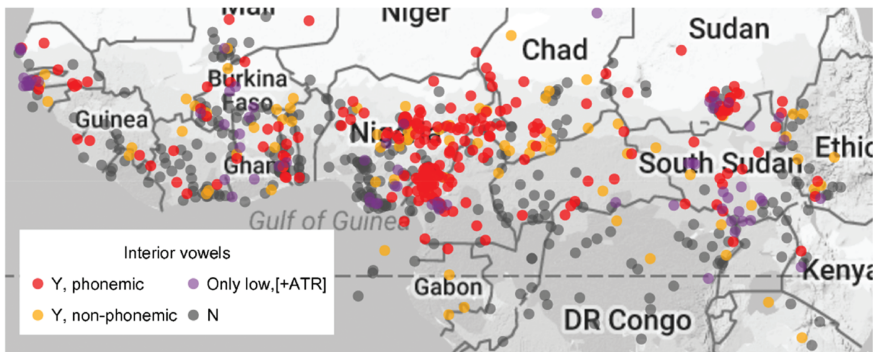


Figure 14: Geographic distribution of interior vowels in Macro-Sudan Belt.

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,

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.

Ubangian, Kainji, Platoid, Jukunoid, West Chadic, Biu-Mandara Chadic, Masa Chadic, East 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 families Bantoid and Delta Cross 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 /i 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 ī 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 [i u 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’ [kím]~[kám], /ùkù/ ‘fox-like animal’ [ùkù]~[ùkà], and /kpók/ ‘cut into pieces (with a knife) [kpók]~[kpák]. A list of languages showing interior allophony is in Table 17 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~i/ 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 /ou/ > [ø] (Grassfields Bantu – Schultz 1993, Matthew Faytak field notes).

One noteworthy observation is that despite the prominence of interior vowels, we found no clear case in which /u/ is the sole high back vowel to the exclusion of /u/. This type of system is well-known from, for instance, the Japanese phonemic inventory /i e a o u/, where the final vowel is phonetically unrounded [u]~[ü]~[̥ü]~[̥̥ü]~[̥̥̥ü] (Okada 1999: 118), and is the sole high back phoneme. Of languages containing [u], systems like Japanese where /u/ 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. 1973) where the vowel quality [u] is only attested as an allophonic variant of /i/.

Let us return to Figure 14 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.¹⁰

Those languages whose only phonemic interior vowel was [+ATR] /ɔ̄/ (the purple dots on the map in Figure 14) 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 vowels altogether. Most conspicuous is the large concentration of gray 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

10 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 [i] and [ə] (cf. long /ii/ [ii], /ee/ [ee] – Konoshenko 2011), Kwa, e.g. Abe [aba] where /e/, /o/ have an allophone [ə] (Dumestre 1971; N'Guessan 1983) and Nawuri [naw] with centralized allophones /i/ > [i], /ɪ/ > [ɪ], /e/ > [ɘ], /ɛ/, /a/ > [ɜ], /a/ > [ɛ] (Casali 1988, Casali 2002; Snider 1989; Lange 1996), and Gur/Senoufo languages, e.g. Cebaara Senoufo [sef] involving centralization of short vowels /i/ > [i], /e/ > [ə], /a/ > [ʌ] (Mills 1984: 99).

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.*).

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 full [ATR] contrast 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] /i/ and [-ATR] /ɨ/~ə/, and the first two also contrast a non-high interior pair [+ATR] /ə/ vs. [-ATR] /ʌ/.

Table 8: Guiberoua Bété.

[ATR]	Front	Central	Back
+	i	ɨ	u
-	ɪ	ʌ	ɔ
+	e	ə	o
-	ɛ	ʌ	ɔ
∅		a	

Table 9: Kanembu.

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

Table 10: Tima.

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

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] /i/ and [-ATR] *ɪ,*ɔ have become [-ATR] /ə/ (Tucker 1964; Hall et al. 1973: 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 11.

Table 11: Strict and liberal designations.

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

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 15 shows strict ATR and strict interiority, while Figure 16 shows liberal ATR and 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 gray dots are those languages with neither.

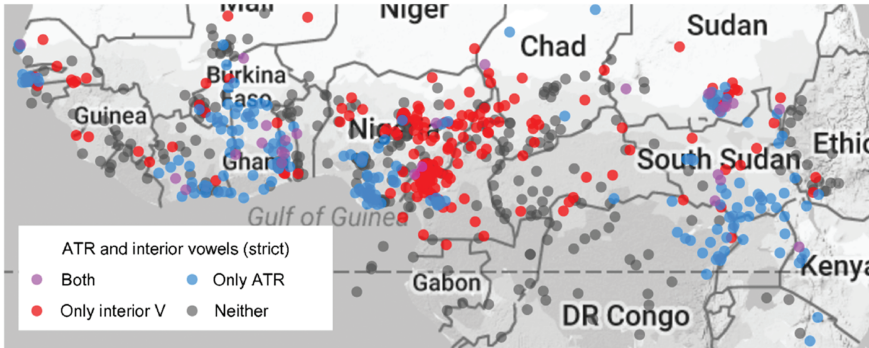


Figure 15: Distribution of strict ATR and strict interiority.

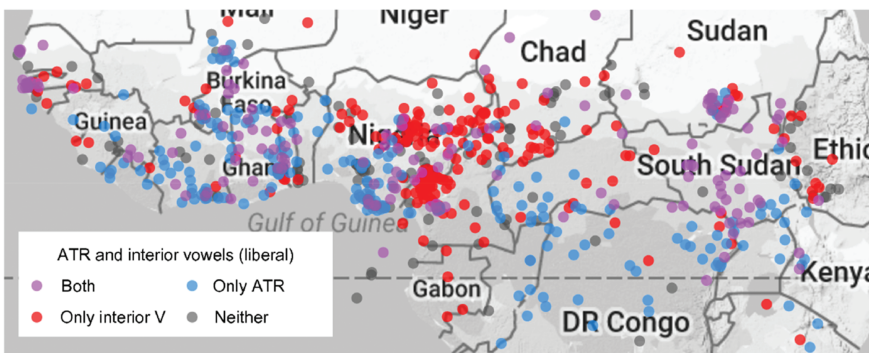


Figure 16: Distribution of liberal ATR and liberal interiority.

The strict ATR and strict interiority map in Figure 15 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 gray dots in the whole map, $n = 289$).

In comparison, the liberal ATR and liberal interiority map in Figure 16 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 Figures 17 and 18 below. As above, certain languages are indicated acting as landmarks.

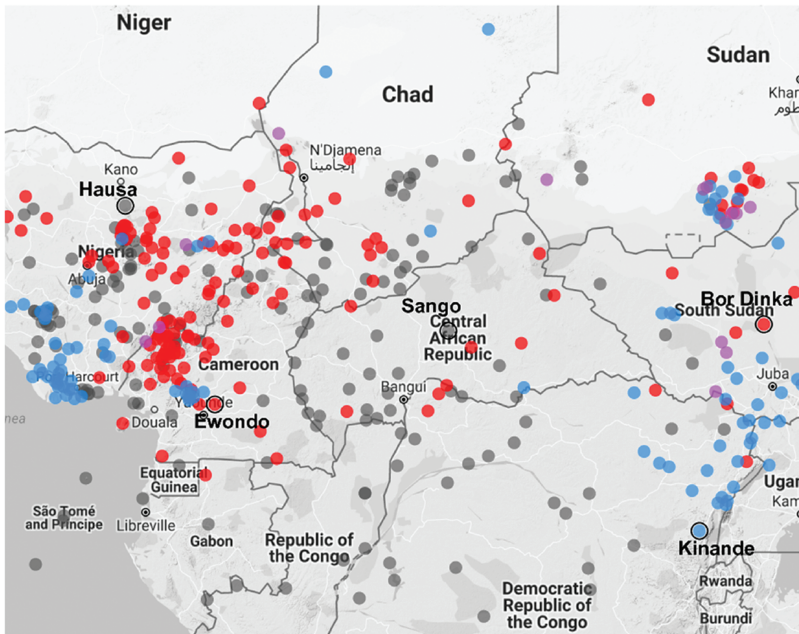


Figure 17: Central Africa – strict ATR by strict interiority (blue = ATR, red = interiority, purple = both, gray = neither).

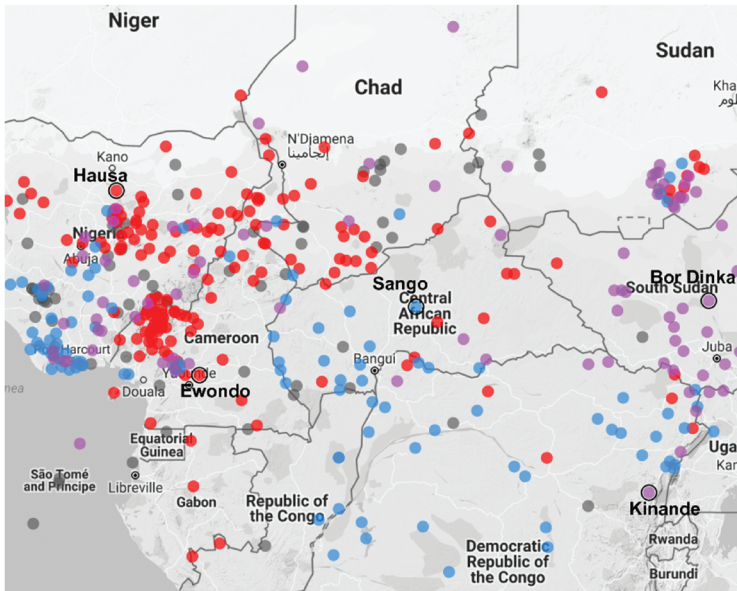


Figure 18: Central Africa – liberal ATR by liberal interiority (blue = ATR, red = interiority, purple = both, gray = neither).

The first map in Figure 17 represents strict definitions. This map shows that there are a significant number of gray 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 18 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 which includes virtually all of Cameroon, southern Chad, and northeast Nigeria.¹¹

¹¹ An anonymous reviewer points out that we do not “tackle the principal methodological problem of identifying a compact areal feature distribution ... concretely, what kind of distributional gaps are admissible for any area to be still accepted as such?”. To view the Central African ATR deficient zone as an insignificant gap, tolerable within the definition of a linguistic area, is missing an important piece of information. This gap is a systematic absence of a typologically marked feature over a very large area involving hundreds of languages from

From this distribution we can establish isoglosses which delineate areas with distinct phonological profiles. Using the strict map in Figure 15 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 16 also largely complies with this Nigerian ATR boundary, albeit with purple dots on either side.

Further, the strict map in Figure 15 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 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 interiority boundary due to the intermixing of gray 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 for each possible combination of strict and liberal ATR and interiority.

dozens of language families. In this sense, it is quite different from lower-scale gaps such as that between the Eastern and Western halves of the West African ATR zone, much smaller in size, much less linguistically diverse, and partly explainable through the recent loss of ATR contrasts in Yoruboid and Edoid varieties. We certainly accept that there are gaps within ATR zones which require additional explanation (outside of the scope of this paper). But we contend that gaps at different scales cannot be said to be of the same nature, or have the same meaning or consequences for our understanding of the structure and historical dynamics of linguistic areas. We do, however, agree with Güldemann (2008, 2010, 2018b: 492–493) that gaps in the distribution of macro-areal features are not necessarily to be interpreted as evidence against the macro-area in question. We will come back to this issue of distributional gaps in defining linguistic (macro-)areas in Section 6.

The results of these tests, shown in Table 12, reveal that strict interiority and ATR (whether liberal or strict) are not independent of one another. This is shown in the two panels in the left column. However, for the liberal definition of interiority (right), only liberal ATR harmony is not independent; strict ATR and liberal interiority does not reach significance (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.

Table 12: Pearson's Chi-square tests for the four possible combinations of ATR and interiority variables (strict and liberal).

Strict ATR/strict interiority	Yes IV	No IV	Strict ATR/liberal interiority	Yes IV	No IV
Yes ATR	29	188	Yes ATR	110	107
No ATR	175	289	No ATR	246	218
$\chi^2 = 40.633, p < 0.001$ (***)			$\chi^2 = 0.234, p = 0.6284$		
Liberal ATR/strict interiority	Yes IV	No IV	Liberal ATR/liberal interiority	Yes IV	No IV
Yes ATR	55	304	Yes ATR	150	209
No ATR	149	173	No ATR	206	116
$\chi^2 = 76.041, p < 0.001$ (***)			$\chi^2 = 32.626, p < 0.001$ (***)		

Furthermore, recall the 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 12 may be interpreted in two ways. One is that interiority and specifically ATR harmony 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 12 but replace 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 ε o ɔ/, /e ε ɔ/, and /ε 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 ε o ɔ].¹² 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 or absence of these phones.

The results of these four chi-square tests are shown in Table 13. All four show a significant non-independent relationship between mid-height contrast and interiority; however, the statistical significance of the relationship of liberal interiority with respect to liberal mid contrast is relatively weak.

Table 13: Pearson's Chi-square tests for the four possible combinations of interiority and mid height contrast variables.

Strict mid contrast/ strict interiority	Yes IV	No IV	Strict mid contrast/liberal interiority	Yes IV	No IV
Yes mid contrast	129	377	Yes mid contrast	242	264
No mid contrast	75	100	No mid contrast	114	61
$\chi^2 = 17.864, p < 0.001$ (***)			$\chi^2 = 14.943, p < 0.001$ (***)		
Liberal mid contrast/ strict interiority	Yes IV	No IV	Liberal mid contrast/liberal interiority	Yes IV	No IV
Yes mid contrast	159	434	Yes mid contrast	299	294
No mid contrast	45	43	No mid contrast	57	31
$\chi^2 = 20.463, p < 0.001$ (***)			$\chi^2 = 5.764, p = 0.0164$ (*)		

At first glance, Table 13 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 retain only languages with Incomplete ATR harmony or with No ATR Harmony ($n = 464$). The results are shown in Table 14 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 12 strict ATR by liberal interiority was not significant, in Table 14 it is the liberal mid contrast by liberal interiority which is not significant.

¹² 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.

Table 14: Pearson's Chi-square tests of mid contrast by interiority *Excludes Complete ATR harmony* ($n = 464$).

Strict mid contrast/ strict interiority	Yes IV	No IV	Strict mid contrast/ liberal interiority	Yes IV	No IV
Yes mid contrast	106	214	Yes mid contrast	151	169
No mid contrast	69	75	No mid contrast	95	49
$\chi^2 = 9.2497, p = 0.002355 (**)$			$\chi^2 = 14.0685, p < 0.001 (***)$		
Liberal mid contrast/ strict interiority	Yes IV	No IV	Liberal mid contrast/ liberal interiority	Yes IV	No IV
Yes mid contrast	131	249	Yes mid contrast	193	187
No mid contrast	44	40	No mid contrast	53	31
$\chi^2 = 8.644, p = 0.003281 (**)$			$\chi^2 = 3.7028, p = 0.05432$		

More telling is Table 15 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 15 shows that this is not the case.

Table 15: Pearson's Chi-square tests of mid contrast by interiority *Excludes Complete and Incomplete ATR harmony* ($n = 322$).

Strict mid contrast /strict interiority	Yes IV	No IV	Strict mid contrast /liberal interiority	Yes IV	No IV
Yes mid contrast	80	100	Yes mid contrast	111	69
No mid contrast	69	73	No mid contrast	95	47
$\chi^2 = 0.5491, p = 0.44867$			$\chi^2 = 0.9438, p = 0.3313$		
Liberal mid contrast/ strict interiority	Yes IV	No IV	Liberal mid contrast/ liberal interiority	Yes IV	No IV
Yes mid contrast	105	133	Yes mid contrast	153	85
No mid contrast	44	40	No mid contrast	53	31
$\chi^2 = 1.3891, p = 0.2386$			$\chi^2 = 0.004, p = 0.9496$		

If all types of ATR harmony languages are removed, the relationship between mid contrast and interiority fails to reach significance regardless of strict or 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-Sudanic 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 19. At the top of this figure, we repeat the proposed areas from Clements and Rialland (2008: 37), Güldemann (2011: 110), and Güldemann’s (2018b: 473) maps respectively for comparison.

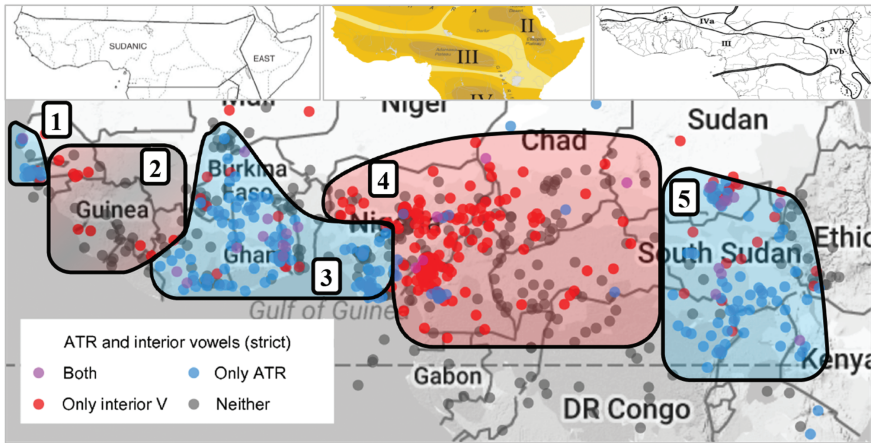


Figure 19: Five areal zones defined by vocalic systems in the Macro-Sudanic Belt (map = strict ATR by strict interiority): [1] Atlantic ATR zone, [2] Guinean ATR-deficient zone, [3] West African ATR zone, [4] Central African ATR-deficient zone (includes Central African interior vowel zone), [5] East African ATR zone.

The most genetically homogenous and smallest zones among these are 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 our findings support or contradict the Macro-Sudan/Sudanic Belt hypothesis. We will concentrate mostly on Güldemann's (2008, 2010, 2018b) proposal, which is the most detailed and comprehensive to date. Before we can start evaluating the relevance of our findings for Güldemann's proposal, however, it is necessary to say a word about its evolution, in particular the differences between his initial (2008, 2010) proposal, and its latest version (2018b). We already mentioned the major differences in terms of the geographical extent of the Macro-Sudan Belt in Section 2.1 above, with the recognition of a Central transition sphere consisting of a Sahel transition zone into the Afroasiatic spread zone to the north, and an East Sudan-Gregory Rift transition zone into the Chad-Ethiopia macro-area to the East. Another major difference is in the list of diagnostic features of the Macro-Sudan Belt, as already shown in Table 1 in Section 2.1. Crucially for our purposes, ATR harmony, initially included as one of the main defining features of the macro-area by both Clements and Riailand (2008) and Güldemann (2008, 2010), is replaced in Güldemann's (2018b) latest version of the proposal by a more general feature defined as '7+vowel qualities.'

Güldemann's (2008) initial survey of Macro-Sudan-Belt languages includes all languages described in the literature as having ATR contrasts and/or ATR harmony, irrespective of the exact definition (phonetic, phonological) of the label 'ATR' by the different authors consulted. As a result, Güldemann (2008: 160) identifies one continuous ATR zone centered on Central Africa and extending far into West and East Africa. With our phonological definition of 'strict ATR languages' as consisting only of languages with attested cross-height harmony, the distribution of 'ATR languages' changes substantially from Güldemann's (2008), whose continuous ATR zone is now split into two separate zones: the West African and East African ATR zones respectively, separated by a very large ATR-deficient zone in Central Africa (to which one must add the small Atlantic ATR zone). Our results thus clearly show that ATR-harmony, despite being highly prevalent in the Macro-Sudan Belt, is characterized by a discontinuous distribution, confirming previous preliminary observations such as Dimmendaal (2001).

Güldemann's (2018b) response to the problem posed by the loose definition of the feature [ATR] in the sources (highlighted as early as Idiatov (2009: 1394–1395) and mentioned in Section 3.1 above) is to recast this feature in terms of vowel system complexity: the Macro-Sudan Belt is no longer said to be characterized by the prevalence of ATR-harmony alone, but by vowel systems consisting of at least seven vowel qualities and "(which includes ATR systems, cf. Güldemann 2018a: 351)." While this new feature may well be characteristic of the Macro-Sudan Belt, it seems to us to be problematic in at least three respects. First, one may wonder whether it is not a little too inclusive to be a useful criterion. Whereas Maddieson's (2013) map of 'vowel quality inventories' clearly shows that 7+vowel

systems in Africa are largely concentrated in what corresponds to Güldemann's (2018b) Macro-Sudan Belt and East Sudan-Gregory Rift transition zone while mostly absent in the Afroasiatic and Bantu spread zones and the Kalahari Basin Area, it remains to be demonstrated whether the feature being mostly absent from the adjacent Chad-Ethiopia macro-area is not simply due to a sampling bias.

Second, more generally having a certain number of vowel qualities is not a property in the same sense as having ATR-harmony, or implosive consonants, or OBJ-V-OTHER word order. This criterion relies on counting, and on deciding on a meaningful threshold (here seven vowel qualities rather than six or eight), which is always partly arbitrary, contrary to the presence vs. absence of a well-defined property.

Third, eliminating ATR harmony as a characteristic feature of the Macro-Sudan Belt by enveloping it in the more loosely defined category of '7+vowel qualities' does not seem to us to be warranted. Despite its discontinuous distribution, and its presence in what Güldemann calls the East Sudan-Gregory Rift transition zone (i.e. outside of the Macro-Sudan Belt strictly speaking), we still think that ATR harmony should be explicitly considered a feature typical of this macro-area. Nowhere else in Africa, nor in the world, is this feature so prevalent with such a wide distribution. The areal nature of this feature is also clear, including in the East African ATR zone, where it cannot be attributed to Nilotic languages only (many of which do not have it, e.g. south-eastern Surmic languages such as Tirma and Chai, among others, cf. Dimmendaal 2001: 363, 373). Indeed, many 'Kordofanian' languages, which are genetically quite diverse (cf. Güldemann 2018a: 223–225), have this feature, as well as the Central Sudanic, Ubangi (Zande), and even Bantu languages (e.g. Kinande) spoken in the region, contrary to related languages outside this area. This actually confirms the Macro-Sudan Belt hypothesis, understood as a macro-area wherein linguistic features spread more easily compared to spreading into other regions, without necessarily showing uniformity, in particular in terms of their distribution.

The discontinuous nature of the distribution of ATR-harmony in the Macro-Sudan Belt and its periphery is certainly very intriguing. The fact that the West- and East-African ATR zones are separated by the immense Central African ATR-deficient zone is striking, as well as the antagonistic relationship between ATR harmony and interior vowels. We contend that this distribution is crucial for the understanding of the structure of the Macro-Sudan Belt, and perhaps for the understanding of how macro-areas in general come to be historically. This is totally missed if ATR harmony is not explicitly considered a Macro-Sudan Belt feature.

There are at least two consequences of viewing ATR harmony as a definitional feature of the Macro-Sudan Belt, which are mostly due to its discontinuous distribution. First, it potentially complicates a straightforward understanding of the Macro-Sudan Belt as containing a core 'hotbed' plus a periphery. As introduced above, Güldemann (2008, 2010, 2011, 2018b) identifies as the 'hotbed' of

Macro-Sudan Belt a region centered around Cameroon and the Central African Republic, replicated in the middle map at the top of Figure 19 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'.

ATR harmony, if defined as a Macro-Sudan Belt feature, is one more feature that is mostly unattested in the macro-area's hotbed. While this does not by itself contradict the existence of Güldemann's hotbed overall, the exclusion of ATR, together with the other features mentioned in the quote above, constitutes a striking gap worthy of consideration. One might wonder therefore whether this macro-area has the concentric structure schematically proposed by Güldemann (2008, 2010), or if it is simply a continuum of overlapping areas, with no hotbed.¹³ The existence of a Central African linguistic area, discussed in the next section, is also particularly relevant for the understanding of the structure and historical dynamics of the Macro-Sudan Belt. The absence of ATR in this area is a very important characteristic in our opinion and this is completely missed if ATR harmony is not explicitly considered a Macro-Sudan Belt criterion.

Finally, the implications that the discontinuous distribution of ATR-harmony may have for the understanding of the linguistic history of this entire region and the diachronic emergence and evolution of the macro-area are completely ignored if one does not include the presence vs. absence of ATR-harmony as a relevant feature of the macro-area. We return to this point in Section 6.4.

6.2 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 [v] (Olson & Hajek 2003; Anonby 2007; Güldemann 2008: 169), S-V-O-NEG word order (Dryer 2009;

¹³ This is closer to Güldemann's (2018b) most recent map of the Macro-Sudan Belt (Figure 4). Note that the notion of "hotbed" plays a reduced role in Güldemann's (2018b) proposal, but is not explicitly abandoned or modified.

Idiatov 2018), and minimal-augmented pronoun systems (Güldemann 2008: 169–171). Maps showing the first two features are provided in Figures 20 and 21 below from their original sources.



Figure 20: Distribution of the labial flap in Africa (Anonby 2007: 3).

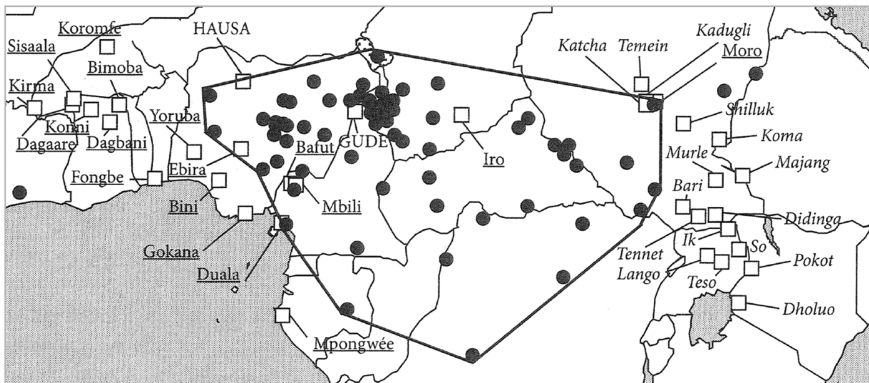


Figure 21: Order of verb and negative among VO languages in Central Africa (Dryer 2009: 323) (black circles are VO languages with V-Neg order, delineated with solid line; white squares are VO languages with Neg-V order).

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. In his examination of clause-final negation markers, Idiatov (2018) acknowledges a Western Focal Area and a Central Focal Area where such markers are disproportionately common, with a major discontinuity around Ghana/Togo/Benin. The Central Focal Area largely lines up with Dwyer's map

above, and Idiatov notes that a good candidate for the core of this area is along “the Benue River corridor going from central Nigeria through northern Cameroon into southern Chad” (p. 147), with the “most important concentration of languages ... found in the area around the border between Cameroon and Nigeria” (p. 134). This lines up with where we find the greatest concentration of interior vowel prominence in our Central African Interior Vowel zone.

Interestingly, Idiatov (2018: 146–151) dismisses the Southern Chad/Central African Republic region, where V-O-NEG seems to be most prominent on the map in Figure 22, as the core of the Central Focal Area, mostly on the basis of historical and demographic considerations. This region mostly corresponds to Güldemann’s proposed hotbed of the Macro-Sudan Belt. The fact that both the Clause-final negation marker area and Central African Interior Vowel zone include part of Güldemann’s claimed hotbed, but are centered further north, and include languages that Güldemann considers to be either at the periphery of the Macro-Sudan Belt or in the Sahel transition zone (e.g. many if not most Chadic languages), is noteworthy, as it seems to potentially complicate the

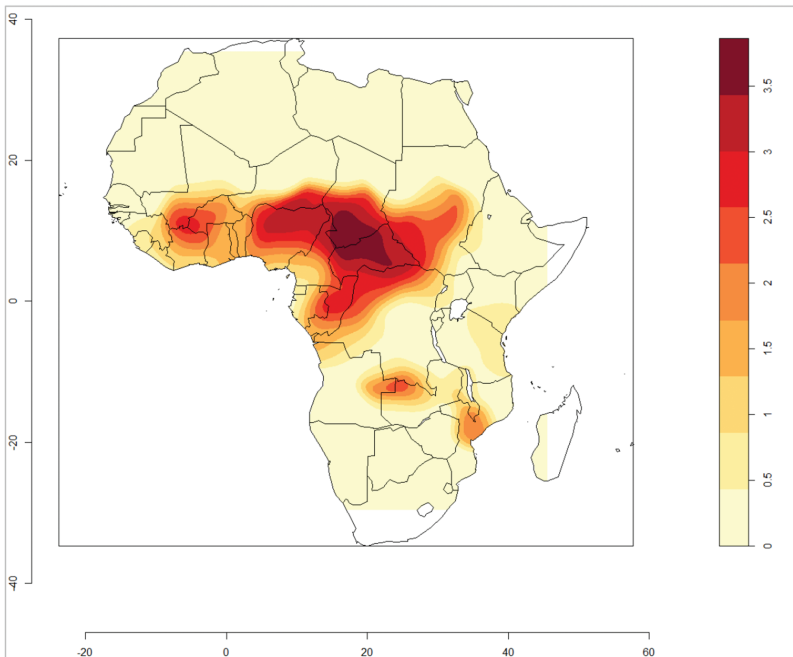


Figure 22: Distribution of clause-final negative markers in Africa (using Gaussian kernel smoothing, the default bandwidth value adjusted by 1.3) (Idiatov 2018: 139).

establishment and exact definition of the hotbed of the Macro-Sudan Belt. The exact distribution of each of the features involved in defining the Macro-Sudan Belt thus needs to be closely examined in order to test (and eventually refute, refine, or strengthen) Güldemann's claim. Such a task is beyond the scope of the present paper, but we hope to have provided materials for further reflection.

6.3 Development of ATR and interiority

As it stands, the precise connection between the three ATR zones demarcated in Figure 19 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 ATR Zone, as most of the languages with ATR-harmony in these two areas are Niger-Congo, and 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, but by no means solely 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 largely 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. Plausible candidates for the absence of ATR in the Guinean and Central African ATR-deficient zones are intrusions by the Mande and Chadic families, respectively. One important aspect of this hypothesis to investigate is 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 3 in Section 3.1 above). More research is required, especially in how ATR harmony is implemented articulatorily across the three ATR zones, in order to more seriously assess this hypothesis.

Related to this line of inquiry, the diachronic relationship between ATR and interiority requires substantial further investigation. We sketch several plausible sequences of historical developments in example (6) below. The first diachronic pathway is ‘loss-before-gain’, in which either ATR or interiority is lost first, then only later does the other develop. The second is ‘gain-before-loss’, in which 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 Tables 8–10 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 i u/
Interior loss before ATR gain	/i i u/	/i u/	/i ɪ u ʊ/
b. Gain-before-loss	Stage 1	Stage 2	Stage 3
ATR gain before interior loss	/i i u/	/i ɪ i ə u ʊ/	/i ɪ u ʊ/
Interior gain before ATR loss	/i ɪ u ʊ/	/i ɪ i ə u ʊ/	/i i u/
c. Direct	Stage 1	Stage 2	
ATR directly to interior	/i ɪ u ʊ/	/i i u ʊ/	
Interior directly to ATR	/i i u ʊ/	/i ɪ u ʊ/	

Each of these three idealized scenarios has yet to 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 the 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] *i *ə and [-ATR] *ɪ *ʌ are reconstructed as allophonic variants of front vowel counterparts, e.g. Proto-Guang */ki-tiŋ/ *[ki-tiŋ] ‘piece’ > Gonja [ki-fiŋ], Chumburung [ki-tiŋ], and Gichode [gɪ-dɪŋ].

Finally, one promising topic for exploration is the role [-ATR] high vowels play in these diachronic scenarios. Such vowels are perceptually weak and therefore may either be lost (e.g. merged with either [+ATR] high vowels /i u/ or [+ATR] mid-vowels [e o]), or trigger harmonic processes to ‘support’ them, as discussed in

Rose (2018: 7; see Casali 2003: 342 for references). Another strategy which may increase perceptual distinctiveness is centralization (e.g. /ɪ ʊ/ > /i ʊ/), which could plausibly contribute to a breakdown of harmony processes and erode the importance of the [±ATR] distinction.

6.4 Historical correlates and linguistic diachrony

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 contact 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 19 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-areas 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 vowel 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 and 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, cf. Güldemann 2018b: 503–507) or primarily longitudinally?

Examining one language family in particular is fruitful: 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 2 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 ($n = 19$). Similarly, 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), 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 23, repeated from Boyeldieu (2006).

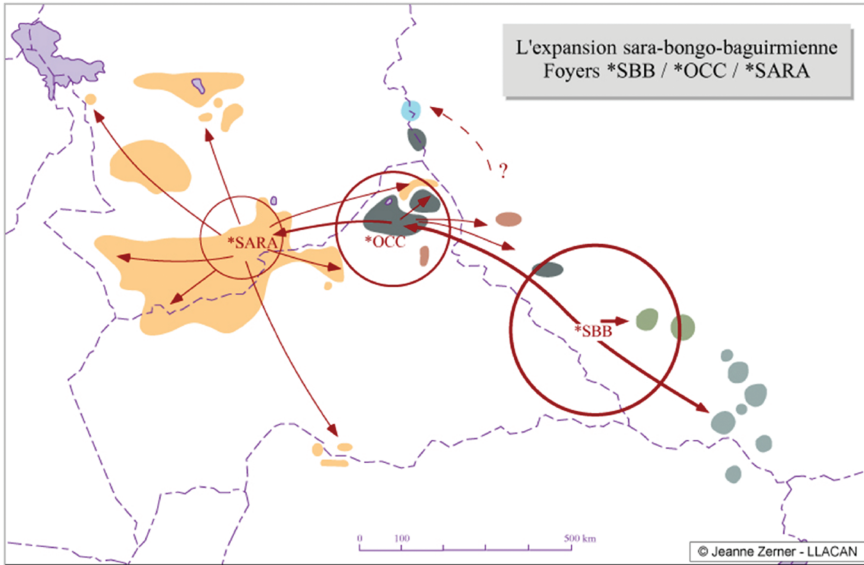


Figure 23: Migrations of Sara-Bongo-Bagirmi (SBB – Boyeldieu 2006).

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).¹⁴ 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 are also particularly

¹⁴ Boyeldieu (2006, among others) remains agnostic as to whether proto-SBB is to be reconstructed with ATR, but does not consider it an unlikely hypothesis (pers. comm. November 2018).

revealing.¹⁵ 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 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. forthcoming). 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 2008: 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 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 ancestor within Niger-Congo), 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.

15 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 & Sterk 1977; Bennett 1983; Kleinewillinghöfer 1996; Güldemann 2018a, among others). 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.

7 Conclusion

In conclusion, this paper provides the most up-to-date mapping of vowel systems in the Macro-Sudan Belt, focusing specifically on ATR-harmony systems and the presence of interior vowels. We have shown that ATR-harmony is disproportionately present in the Macro-Sudan Belt, making it a characteristic feature of this macro-area (cf. Clements & Rialland 2008; Güldemann 2008, Güldemann 2010; but *contra* Güldemann 2018b). We have also shown that this feature has a discontinuous distribution in the macro-area, with three separate ATR-zones, notably the West and East African ones, separated by an immense ATR deficient zone area, confirming previous cursory surveys of this feature (e.g. Dimmendaal 2001). This discontinuous distribution is intriguing and worth considering in any further work on the Macro-Sudan Belt, and on the notion of ‘macro-area’ in general, since it points to both a complex synchronic organization of this macro-area, as well as complex historical scenarios for its emergence. Specifically, at the very least it complicates Güldemann’s notion that the hotbed of the Macro-Sudan Belt is in Central Africa.

We have also shown that the Central African ATR deficient zone largely overlaps with a large region where languages overwhelmingly tend to have interior vowels, either phonetically or phonemically. This Central African Interior Vowel zone further overlaps significantly with other isoglosses, notably clause-final negation, the labial flap, and minimal-augmented pronoun systems. This seems to warrant the idea that Central Africa is a linguistic area of its own, within the Macro-Sudan Belt. The fact that this area overlaps with Güldemann’s proposed hotbed of the Macro-Sudan Belt, but seems to be centered further north, is an additional interesting fact to take into account in evaluating any hotbed hypothesis.

The inverse correlation between the distributions of ATR-harmony and interior vowels in the Macro-Sudan Belt is one of the main contributions of this paper. Although we do not venture into specific diachronic scenarios, we provide a few telling examples of languages and language families that seem to have changed their overall vowel system profiles when changing areas: losing ATR-harmony and/or gaining interior vowels when moving into the Central African Interior Vowel Zone, or vice versa. Further research will determine both the historical events and the step-by-step linguistic changes involved in such profile shifts.

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Author contribution statement: The database was developed by all three authors. NR encoded the majority of languages in the database. The body of this paper was first written by NR, followed by significant revisions and contributions from the other authors. The discussion Section 6 was developed by FL. The statistics and maps were developed by MF.

Appendix

Table 16: Families by ATR and Interiority value Niger-Congo (NC – $n = 487$), Nilo-Saharan (NS – $n = 119$), Afroasiatic (AA – $n = 66$), Creole & Other ($n = 9$).

Family	n	ATR			Interiority			
		Complete	Incomplete	No	Phonemic	Non-phonemic	[+ATR, +low]	None
NC Bantu	69	20	23	26	11	4	6	48
Atlantic	31	14	3	14	9	2	12	8
Adamawa	26	2	6	18	13	3	0	10
Potou-Tano	26	21	3	2	3	2	4	17
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
Other Kwa	17	8	7	2	3	3	1	10

(continued)

Table 16: (continued)

Family	n	ATR			Interiority			
		Complete	Incomplete	No	Phonemic	Non-phonemic	[+ATR, +low]	None
Platoid	17	2	4	11	6	4	1	6
West Mande	17	0	12	5	3	2	0	12
South Gur	16	14	1	1	2	3	6	5
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
Delta-Cross	11	5	5	1	1	0	4	6
Ijoid	10	8	2	0	0	0	0	10
Jukunoid	10	1	0	9	6	0	0	4
Dogon	9	1	8	0	0	1	1	7
Gbe	9	0	0	9	3	0	0	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
Defoid	6	3	3	0	0	0	0	6
Idomoid	6	1	4	1	1	0	1	4
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
East Kru	4	4	0	0	2	0	0	2
NS Central Sudanic	40	19	2	19	7	14	8	11
Other NS	29	14	2	13	8	4	5	12
Nilotic	25	19	5	1	7	1	7	10
Surmic	9	4	0	5	0	2	1	6
Songhai	7	0	2	5	1	0	0	6

(continued)

Table 16: (continued)

Family	n	ATR			Interiority			
		Complete	Incomplete	No	Phonemic	Non-phonemic	[+ATR, +low]	None
Maban	5	0	1	4	2	2	0	1
Saharan	4	3	0	1	2	1	1	0
AA West Chadic	18	1	0	17	12	3	0	3
Biu-Mandara	15	0	0	15	12	3	0	0
Other AA	12	2	0	10	6	1	1	4
East Chadic	10	0	1	9	3	1	0	6
Omotic	9	0	0	9	1	3	0	5
Creole	6	0	1	5	1	2	0	3
Other	3	0	2	1	2	0	0	1
TOTAL	681	217	142	322	204	83	69	325

Table 17: Sample of languages in or near the Central African interior vowel zone which only have allophonic interior vowels.

Language	ISO	Interior allophony	Genetic group	Source
Mambila	mcu	/u/ > [y] /e/ > [ə]	Bantoid	Perrin (1987), Connell (2007)
Noni	nhu	/e/ > [ə] /ɛ/ > [ɛ̃]	Grassfields Bantoid	Hyman (1981)
Njebi	nzb	/V/ > [ə]	Bantu	Blanchon (1999)
Boma	boh	/a/, /ɔ/, /ɛ/ > [ə] /_r	Bantu	Stappers (1989)
Amo	amo	/i/ > [i] / ._.C. /u/ > [u] / ._.C.	Kainji, Benue- Congo	Di Luzio (1972)
Bo-Rukul Fyem Horom	mae pym hoe	/i/ > [i] / ._.C.	Platoid, Benue- Congo	Nettle (1998)
Waja	wja	/i/, /u/ ([+ATR]) > [ə] /ɪ/, /ʊ/ ([−ATR]) > [ɜ]	Adamawa	Kleinwillinghoefer (1991)
Mumuye	mzm	/i/ > [i]	Adamawa	Shimizu (1983: 1–24)

(continued)

Table 17: (continued)

Language	ISO	Interior allophony	Genetic group	Source
Tunia	tug	/V/ > [i~u~ə]	Adamawa	Palayer (1975)
Northwest Gbaya	gya	/u/ > [y] /o/ > [ø] /ɛ/ > [œ]	Gbaya	Moñino (1995: 58–68)
Sar	mwm	/V/ > [i]	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/ > [i] /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 Afitti	dzg aft	/V/ > [i] /i/ > [i] / _C.	Saharan Eastern Sudanic(?)	Walters (2015: 24–38) Voogt (2009)
Hausa	hau	/i/ > [i] / _n. /u/ > [u] / _n.	West Chadic	Salim (1977: 133)
Pero Dangaleat	pip daa	/i/, /u/ > [i] /i/, /u/ > [ə]	West Chadic East Chadic	Frajzyngier (1989: 28–53) Ebobissé (1979: 15–18, 24–25); Fédry (1977)

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[Citations to the sources used in our ALFA database are provided in the supplemental materials. Full reference information is largely available on Glottolog.org. Please email us for reference information which is not found there.]

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