1. INTRODUCTION

We offer an initial acoustic description of several features of Southern American English in the Digital Archive of Southern Speech (DASS) (Kretzschmar et al., 2012), a large data set currently under development. DASS is a subset of the Linguistic Atlas of the Gulf States (LAGS) (Pederson et al., 1986). It is an audio corpus of semi-spontaneous linguistic atlas interviews, including 64 speakers native to 8 Southern U.S. states. The speakers are 34 men and 30 women from varied social and racial backgrounds, born 1886 – 1965, and recorded in their homes from 1968 – 1983. A small portion of the larger LAGS corpus has been analyzed in other recent work (Renwick and Olsen, 2016, 2017).

This exploration includes both static and dynamic aspects of vowels that are characterized as *shifting* in major dialects represented by DASS. We test for characteristics of the Southern Vowel Shift (SVS) (Labov et al., 2006; Thomas, 2003) in the speech of European Americans, and for the African American Vowel Shift (AAVS) (Kohn and Farrington, 2013; Thomas, 2007) by African American speakers. Both shifts affect front and back vowels, though in different ways.

In the SVS, tense front vowels /i eɪ/ are characterized as "swapping places" in the vowel space with lax /ɪ ɛ/ respectively, such that the tense vowels centralize and lower while the lax vowels are fronted and raised, as is low /æ/. In the AAVS, by contrast, lax vowels /ɪ ɛ æ/ raise, but their tense counterparts do not necessarily shift; note that we assume Thomas' (2007) version of this shift because it is based on older speakers, like ours, while Kohn's (2013) speakers are several generations younger. Despite the presence of swapping or strong overlap, tense and lax front vowels are not *merged* in Southern or African American varieties, potentially owing to a diphthongal pronunciation that may maintain their distinctness.

Where the back vowels are concerned, SVS speakers are expected to show fronting of /u oʊ/, while AAVS speakers maintain those vowels' backness; this is a characteristic that distinguishes the two vowel shifts, but affects the vowels' static positions rather than their temporal dynamics. We compare the positions of /u, oʊ/ with respect to each other, and across ethnicities. Finally, perhaps the most stereotypical sign of Southern speech is monophthongization of /aɪ/ to [a:]: here, we capture the degree of monophthongization both across demographic groups, and across phonological contexts where monophthongization is either conditioned or blocked (Labov et al., 2006).

In the remainder of this paper, we first describe our corpus and methods, focusing on a subset of DASS speakers for visualization. We describe vowels' relative placement in the F1, F2 vowel space, and then evaluate the amount of overlap among several pairs of vowels using Pillai scores, to reveal the current state of vowel shifting widely described for these speech varieties. While the results are largely consistent with descriptions of the SVS and AAVS, we argue that defining aspects of Southern speech are best captured through vowels' dynamics. We thus also evaluate contrasts between tense and lax front vowels via their inherent spectral change, and illustrate monophthongization of /aɪ/ via calculations of formant angles. The results are plotted and, in some cases, superimposed on maps of this Southern region.

2. ANALYZING THE DIGITAL ARCHIVE OF SOUTHERN SPEECH

We provide a brief overview of the methods used to transcribe, align, and extract acoustic data from DASS, which are covered in more detail by Renwick et al. (2017). This project is ongoing at the University of Georgia; at present, more than 120 hours of speech from 41 speakers have been transcribed.

A. TRANSCRIPTION

Transcription is carried out at the orthographic level by a group of undergraduate research assistants using Transcriber (Barras et al., 2001). The files, in .wav format, are each approximately 1 hour long and contain speech from an interviewer and an interviewee, as well as occasional "auxiliary" speakers, second interviewers, and background noises or interruptions. All intervals of speech and noise are identified in the audio signal and classified using a set of locally defined conventions. Transcribers listen to each file twice, and their transcriptions are afterward checked for correctness and consistency by graduate research assistants. Each interview varies in length, ranging from approximately 2.5 hours to 10 hours. A script accompanying the corpus database software LaBB-CAT (Fromont and Hay, 2012) is used to convert the output of Transcriber into Praat TextGrids (Boersma and Weenink, 2015), which are further processed until their time-aligned intervals correspond only to speech by the interviewee that is non-overlapping and uninterrupted (interviewer speech is not currently analyzed).

B. FORCED ALIGNMENT AND DATA EXTRACTION

Individual TextGrids and .wav files are subjected to forced alignment and linguistic data extraction using the Semi-Automated Alignment and Extraction tool within the Dartmouth Linguistic Automation suite (DARLA) (Gorman et al., 2011; Reddy and Stanford, 2015a, 2015b). DARLA returns TextGrids containing alignments at the word and phone level, as well as a spreadsheet of individual vowel tokens with a variety of acoustic values and linguistic variables per token. At present DARLA does not return measurements for *all* vowel tokens in the data; output is subject to filtering based on a variety of criteria – for instance, DARLA only returns data points for which formant values can be extracted (cf. Renwick et al., 2017 for discussion of extraction method comparison). Crucial for the present paper are two types of formant extractions done by DARLA: following forced alignment, *single-point* F1, F2, F3 is extracted according to vowel-specific heuristics (cf. Rosenfelder et al., 2011's "best" measurement), and an additional unscaled Lobanov transformation (Lobanov, 1971) is conducted for F1, F2. Single-point values are selected from a set of candidate formant tracks, and typically measured at one-third between vowel onset and offset (Evanini, 2009), although vowels in certain contexts are measured e.g. at the point of maximum F1 (see Labov et al., 2013 for details). DARLA also extracts *time-course* F1, F2 at for each token at 20%, 35%, 50%, 65%, 80% of vowel duration (duration data are included in the output). Among the additional linguistic variables extracted based on phonetization of the orthographic transcription are information about preceding and following segments and natural classes, stress, following word, and whether the vowel is word-internal or at a boundary. This spreadsheet is enriched with speaker-specific demographic information and further analyzed using R (R Core Team, 2000).

3. METHODS

DASS is a legacy corpus, consisting of aging recordings of naturalistic speech by a wide variety of speakers made in the field on reel-to-reel tape. For these reasons and others, the dataset is filtered and further processed before analysis is carried out. In this section we describe the speakers whose recordings have been processed, as well as our methods for separately filtering the *single-point* and *time-course* formant measurements on which our results are based.

A. SPEAKERS

As this corpus is undergoing transcription and analysis, data from all 64 DASS speakers is not available. Table 1 describes the dataset at time of writing, providing a broad summary of the number of speakers transcribed for each ethnicity and sex, per state, including the speakers' mean age and the total number of vowel tokens available. In addition to these demographic factors, DASS includes speaker-specific information on: education (years of school); social class; town and county of origin; birth year and interview year (see Kretzschmar et al., 2012 for details on speaker selection). In the results below, we are attentive to high levels of interspeaker variation, and in several analyses present individual results. For brevity's sake we offer individual data from 12 speakers, sampling four states (AL, GA, TN, TX) for which data are available for at least one (a) European American (EA) female, (b) EA male, (c) African American (AA) male. The same 12 speakers are shown in all individual plots. African American speakers (particularly females) are underrepresented in LAGS and in DASS with respect to the population of the southern US, and future analyses will be as balanced as possible with respect to sex and ethnicity.

Table 1. Summary of DASS speakers and vowel tokens included in the present paper

	Female speakers				**Male speakers**			
State	**EA**	**AA**	**Mean age**	**Tokens**	**EA**	**AA**	**Mean age**	**Tokens**
AL	2	0	60	3693	3	1	74	35964

	Female speakers				Male speakers			
State	**EA**	**AA**	**Mean age**	**Tokens**	**EA**	**AA**	**Mean age**	**Tokens**
AR	1	0	40	3189	1	0	68	8666
FL	2	1	57	25524	0	0	*n/a*	*n/a*
GA	2	0	70	9817	3	1	50	21475
LA	2	1	43	24338	2	0	79	30363
MS	2	0	70	8146	3	1	80	48566
TN	5	1	61	28942	3	1	72	43127
TX	2	0	49	15277	3	2	53	23763
Total	18	3	54	118926	18	6	70	211924

B. DATA SELECTION AND FILTERING

This subsection addresses two interacting issues related to data selection: first, we acknowledge that in an acoustic dataset of this size, outliers are present due to e.g. automatic measurement error, undetected errors in transcription or forced alignment, and noise in the signal; thus, not all tokens are expected to accurately represent speakers' production, so the data must be filtered (beyond automatic filtering conducted by DARLA). Second, we filter the data separately for (a) single-point data, and (b) time-course data. These two processes are necessarily independent because while the relevant measurements are done based on the same sets of formant tracks, they are taken separately and at different time points in the vowel; thus filtering time-course data based on single-point formant values could inadvertently exclude non-outliers (or vice-versa). Both procedures discard tokens that lie far from a vowel's central tendency.

i. Single-point data

Single-point data, based on the "best" formant measurements for each vowel type and token, are used for "static" analyses of the vowel space including F1, F2 plots and Pillai scores. We carry out filtering based on Mahalanobis distance (Labov et al., 2013; Mahalanobis, 1936), which is a non-directional distance score based on ellipses. Each token's Mahalanobis distance, which takes both F1 and F2 into account, is calculated relative to a speaker- and vowel-specific centroid. Tokens with high distance (based on the 95% quantile of a χ^2 distribution) are excluded as outliers, reducing the datapoints available to 296,636 (approximately 12% of tokens are filtered). Additionally, the vowel OY /ɔɪ/ is currently excluded due to its rarity in the dataset (see Fig. 1). An advantage of this filtering technique is that both F1 and F2 are considered simultaneously, and the plotted output produces vowel clouds that retain an elliptical shape. While vowels in spontaneous speech may not in fact follow elliptical distributions, the alternative of filtering F1 and F2 values *separately* and without regard for angular distance from a centroid would, for a very large and noisy dataset, produce plotted vowel clouds with unnaturally straight edges.

ii. Time-course data

Time-course data, in which formant values are returned by DARLA at five points during each token, are used for "dynamic" analyses of the vowel space, including plotting trajectories across time and calculating formant change over time. These data are also filtered on the basis of Mahalanobis distance, which is calculated for F1 and F2, on a speaker- and vowel-specific basis, using the 50% (midpoint) measurement of each token. Tokens are excluded as outliers using the same criterion as above, and the resulting time-course dataset contains 295,339 tokens, a reduction of approximately 12.5% with respect to the entire dataset that also includes 41 tokens with missing midpoint values. While the dataset may still contain points that are outliers with respect to the 20%, 35%, 65% or 80% measurements, this filtering method removes tokens that are grossly outlying during their steady state, without reference to more peripheral measurements subject to more fluctuation due to e.g. consonant transitions and coarticulation.

iii. Vowel tokens available

While Table 1 indicates how many vowel tokens are currently available for several demographic groups, data analysis and modeling are ultimately also affected by the unbalanced distribution of vowel types across the corpus, as well as by data shrinkage due to filtering of outliers. Figure 1 compares the number of tokens available per vowel type (not all of which are analyzed here), labeled by ARPABET symbol as assigned by FAVE (Rosenfelder et al., 2011) across the entire corpus vs. the single-point and time-course data. Figure 1 shows the strongly imbalanced distribution of vowels across the corpus, and that all vowels (except the rare OY) are approximately equally impacted by the two filtering procedures.

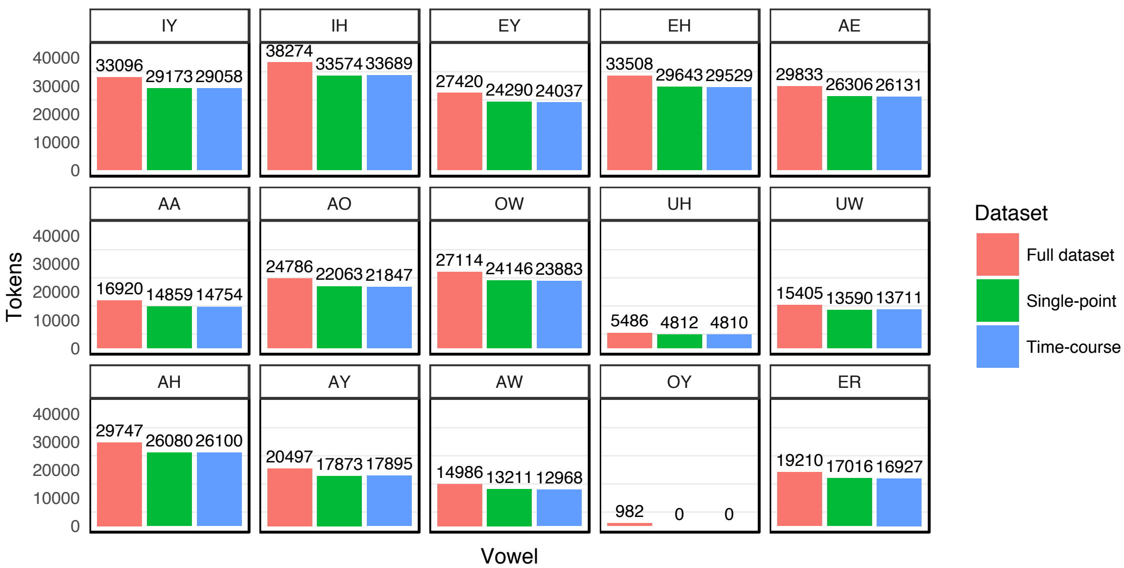

Figure 1. Token counts of vowel types across datasets

4. RESULTS: STATIC MEASURES OF THE VOWEL SPACE

The SVS and AAVS are typically characterized in terms of vowels' relative placements in the F1, F2 vowel space. Most acoustic studies rely on a single measurement point per token, although they differ with respect to where in the vowel values are extracted. Based on the single-point dataset, we present vowel spaces for 12 representative speakers, as well as an analysis via Pillai scores of the relative placements of vowels implicated in the SVS and AAVS.

A. MAPPING THE VOWEL SPACE

Figure 2, below, provides F1, F2 vowel plots for the 12 individual speakers selected to represent DASS. The plots include means, marked by text in the center of each ellipse, which in turn lies at 1 standard deviation from the mean. In the interest of space individual data points are not shown, additionally we excluded unstressed vowels, whose formant values are expected to systematically differ from stressed vowels; vowels preceding sonorants (i.e. nasals and liquids), which cause variation in the vowel space due to coarticulation; and tokens of /u/ after /t, d/, which can trigger greater fronting (e.g. *Tuesday*, *dew*). While these plots exhibit considerable inter-vowel overlap and variation, due to the semi-spontaneous nature of the interview speech, several characteristics of Southern speech can be seen. In most speakers, /ɪ/ is raised, and can overlap heavily with /i/ (e.g. AA speaker 100, the corpus' youngest interviewee). However, overlap between /eɪ ɛ/ is stronger, and for several speakers the central tendency of /ɛ/ is higher than that of /eɪ/ (e.g. 342, 185). /æ/-raising is variable across speakers; compare 434, an AA speaker whose /æ/ overlaps strongly with /ɛɪ ɛ/, vs. 847, a younger AA speaker whose /æ/ is relatively low. Among back vowels, /u/-fronting is clearly present in many speakers, and strongest for speakers like 185, a young Georgian, and 863 and 894 from Texas; their wide age range indicates that this phenomenon is not restricted by generation. On the other hand, /oʊ/-fronting is less prevalent. Generally, AA speakers appear to have lower F2 for both /u, oʊ/ than EA speakers. It is also apparent that the *caught-cot* merger is variable among these speakers, shown by the vowels AO AA, which overlap strongly for e.g. EA speaker 185, but not for e.g. AA speaker 847. This contrast is not further evaluated here. Taken together, these impressionistic results are in keeping with the SVS and AAVS, although the extent to which particular vowels have shifted clearly varies across speakers, and consistent effects of race, sex, or state of origin are not immediately apparent. These effects are tested explicitly in the next section.

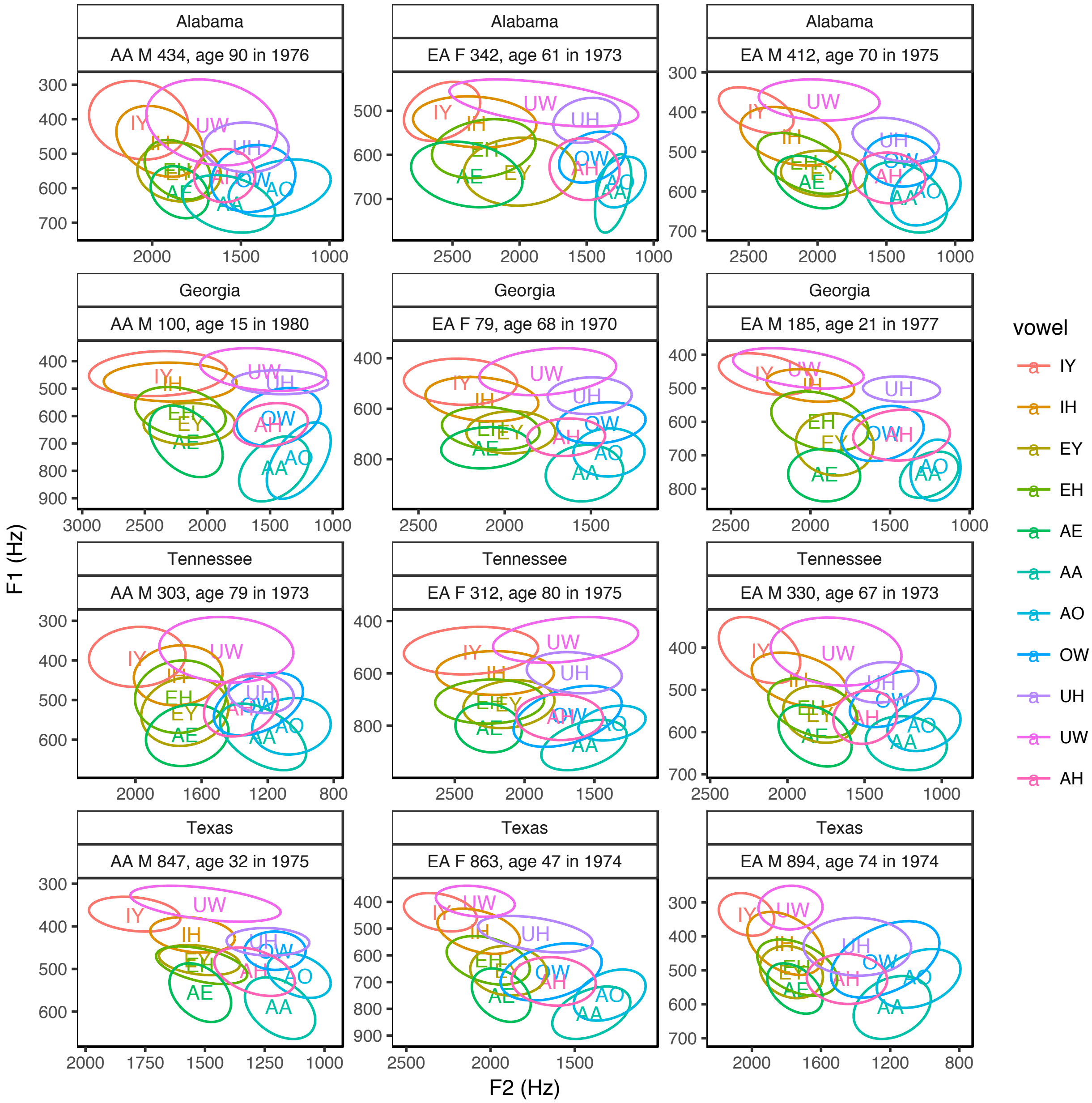

Figure 2. Stressed vowel spaces of 12 speakers

B. PILLAI SCORES

Pillai scores (Hall-Lew, 2010; Hay et al., 2006, *inter alia*) are used to gauge the phonetic distinctness of a particular contrast, typically between two vowels in the vowel space. Pillai scores are relevant to our understanding of Southern speech because in the SVS and AAVS several pairs of vowels are moving towards, overlapping with, or past one another in the vowel space. They are a test statistic associated with a MANOVA, which is run using token-specific values of Lobanov-transformed F1, F2 as dependent variables, with a set of predictors related to phonological context and other independent factors. We constructed separate MANOVAs for each speaker, for each of the following vowel pairs: /i ɪ/; /eɪ ɛ/; /u i/; /oʊ i/. Predictor variables were: preceding consonant; manner, place, and voicing of following consonant;

context (word-initial, word-final, or word-internal vowel); and stress (0, 1, 2). The resulting speaker-specific Pillai score ranges from 0 to 1, where 0 indicates a complete merger, and 0 indicates a strong distinction (no overlap); scores also receive a *p*-value ($p < 0.01$ in all cases tested here), and a significant Pillai score effectively means that the factor "vowel" is a significant predictor of F1, F2. Because "swapping" is described for front vowels in the SVS we adjusted those Pillai scores for the possibility of a vowel *reversal* with respect to phonological expectations: when a speaker's mean F1 value for the phonologically lower vowel (/ɛ, ɪ/) was less than that of the phonologically higher vowel /i eɪ/, we multiplied the lax vowel's Pillai score by −1, giving an effective range of {−1, +1} (see Hall-Lew, 2010 for further discussion). Because Pillai scores are calculated via a single data point (F1, F2) per vowel, we use Mahalanobis-filtered data.

Among the front vowel pairs, we are interested in evidence of the vowels' reversal in the vowel space, as has been described for both the SVS and the AAVS. We are curious whether: (a) there is more evidence of mid-vowel overlap than high-vowel overlap, which would corroborate accounts of the mid-vowel shift's greater age and advancement throughout the South (Fridland, 2003); (b) whether there are reversals, particularly in the mid-vowel pair, indicating that the phonological distinction in height has been phonetically swapped. Among the back vowel pairs, we quantify back-vowel fronting, which is widely described for American varieties but particularly advanced in the South. We anticipate greater Pillai scores (i.e. less overlap) between /oʊ i/, as this change is argued to be more recent and less advanced than /u/-fronting (Kurath and McDavid, 1961; Thomas, 2005), but we do not expect reversals between /i/ and either back vowel. We expect considerable inter-speaker variation.

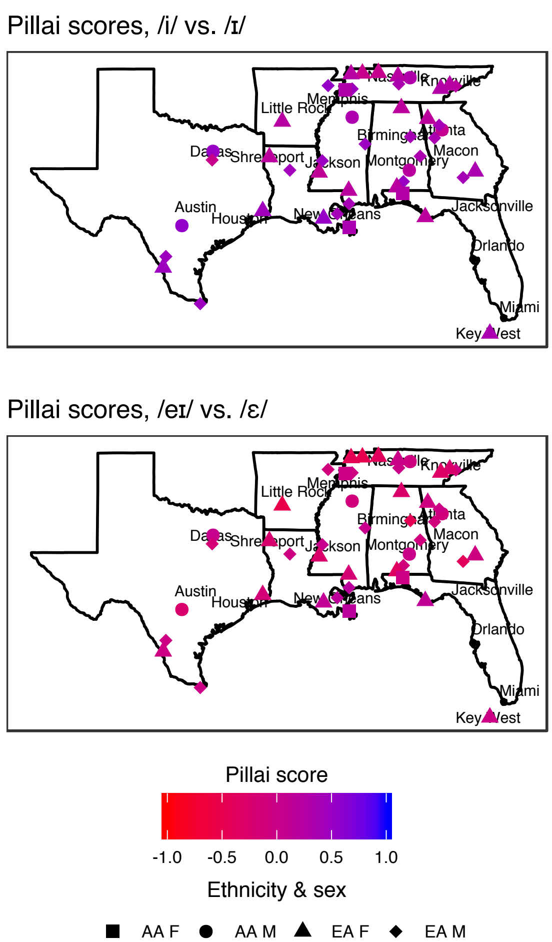

Figure 3. Pillai scores for non-low front vowels

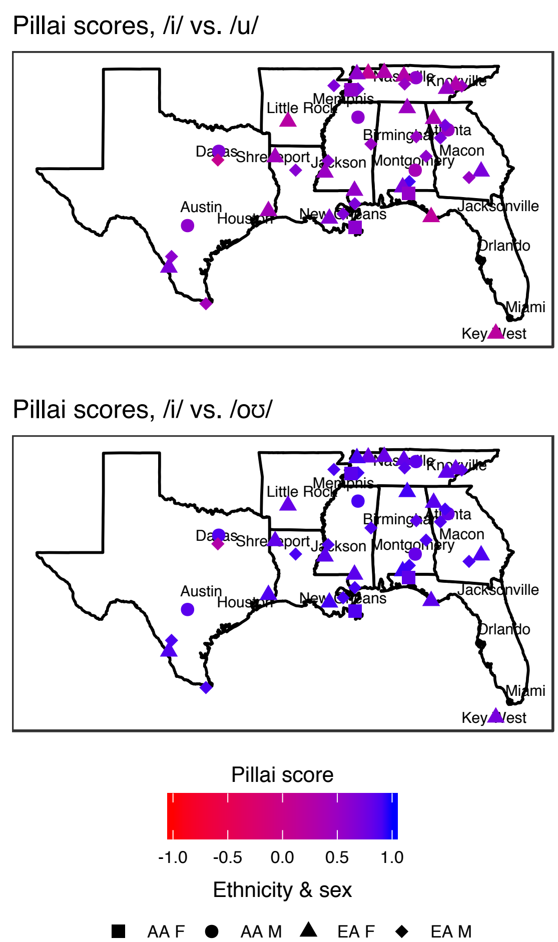

Figure 4. Pillai scores for /i/ vs. /u, oʊ/

Figures 3 and 4 plot each speaker's pair-specific Pillai score as a point located at the latitude and longitude of their hometown. There are no visually obvious geographic trends. Across the two plots, the pair /i oʊ/ has the highest Pillai scores overall, while the lowest Pillai scores are between /eɪ ɛ/; in fact many speakers (33/41) do show a slight reversal of the two mid vowels in the vowel space, producing a negative Pillai score. Planned comparisons of Pillai scores across and within vowel pairs were evaluated via two-sided *t*-tests. The /i ɪ/ pair shows significantly higher Pillai scores than /eɪ ɛ/ ($t(87.248) = 12.931$, $p < 0.001$), and the /oʊ i/ pair has higher significantly higher scores than the /u i/ pair ($t(68.735) = -11.247$, $p < 0.001$), confirming anecdotal observations that are consistent with greater swapping among front mid vowels, and greater fronting of /u/ than /oʊ/. For each of the four pairs, difference in Pillai scores across ethnicity groups was tested; this predictor is insignificant ($p > 0.05$) for all pairs, although for /eɪ ɛ/, where AA speakers have marginally higher Pillai scores than EA speakers ($t(20.071) = 1.9528$, $p = 0.07$), suggesting stronger mid vowel shifting for the latter group. Gender has a significant effect for two pairs, in which males have higher Pillai scores, indicating less overlap (and less shifting) with respect to females: /i ɪ/ ($t(44) = -3.2288$, $p < 0.01$), and /u i/ ($t(41.536) = -2.5427$, $p < 0.05$). This result fits with many others showing that women lead language change. Additionally, our measures can be compared to analyses of more recent data; we predict that present-day Southern men have more shifting than DASS men, providing a nice snapshot of these shifts in real time. Future work on the DASS dataset will apply increased statistical complexity to models of Pillai scores.

5. RESULTS: DYNAMIC MEASURES OF THE VOWEL SPACE

Next we consider how our understanding of Southern shifting in DASS is affected when we use time-course data to examine spectral change and intra-token movement in the vowel space. While sociophonetics increasingly acknowledges the relevance of vowel dynamics to dialect characteristics and speech perception (Haddican et al., 2013; Koops, 2014; Morrison and Assmann, 2013; Risdal and Kohn, 2014), the implications of vowel trajectory shape for characterizations of the SVS and AAVS have not been fully explored. We also test the strength of /aɪ/ monophthongization and its degree of phonological conditioning.

A. VOWEL TRAJECTORIES

According to the SVS and AAVS, and as shown above, front tense and lax vowels can overlap and "swap" in the vowel space; however aside from the well-known *pin/pen* merger (before tautosyllabic nasals), these movements are not claimed to engender merger. By considering the *dynamics* of tense vs. lax vowels in Southern speech, it becomes clear that while these pairs may pass through the same vowel space, they remain acoustically distinct, including by maintaining separate dynamic trajectories. Fox & Jacewicz (2009) illustrated differences in vowel trajectories plotted in F1, F2 space, using measurements across 5 time points to show dynamic movement. We replicate their analysis for front tense and lax vowels /i ɪ, eɪ ɛ, æ/ and the diphthong /aɪ/, by calculating trajectories for each speaker, averaged per vowel and time point for ease of display. The results are shown in Figures 6 – 9, showing tense and lax vowels for individual speakers from each of the four sampled states; results from all speakers are similar.

This illustration reveals that the tense vowels begin at their lowest and most central point, and move up and typically toward the front of the vowel space. This is characteristic of a diphthongal, upgliding production. Lax vowels, however, typically move toward their frontest point with less change in F1 (especially for /ɛ æ/), and in many cases then centralize toward the end of the vowel, creating a trajectory that either lowers or appears to double back on itself in the vowel space. Since these trajectories take place over many milliseconds, and have different starting points, midpoints and end points, their differences are undoubtedly perceptible to listeners; so, /eɪ/ and /ɛ/ are actually quite acoustically distinct. Future work will model these curves in more detail, including inherent durational differences, and examine how the trajectories vary according to sociolinguistic variables.

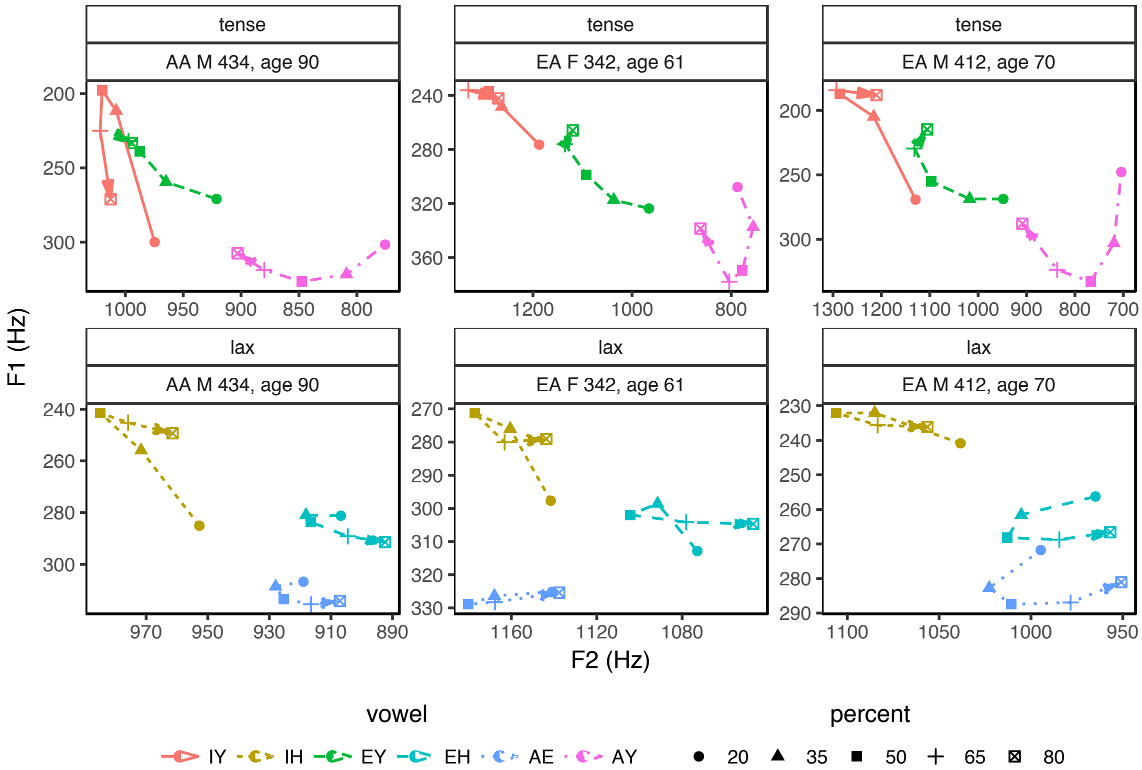

Figure 6. Trajectories for Alabama

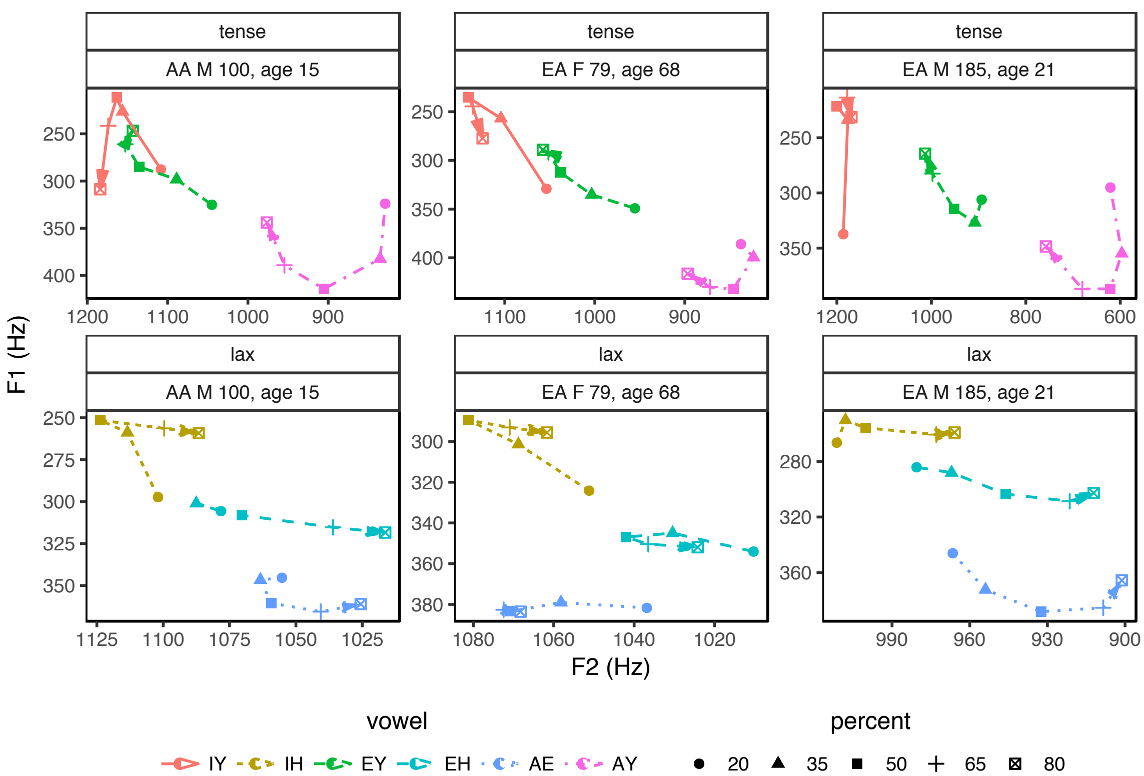

Figure 7. Trajectories for Georgia

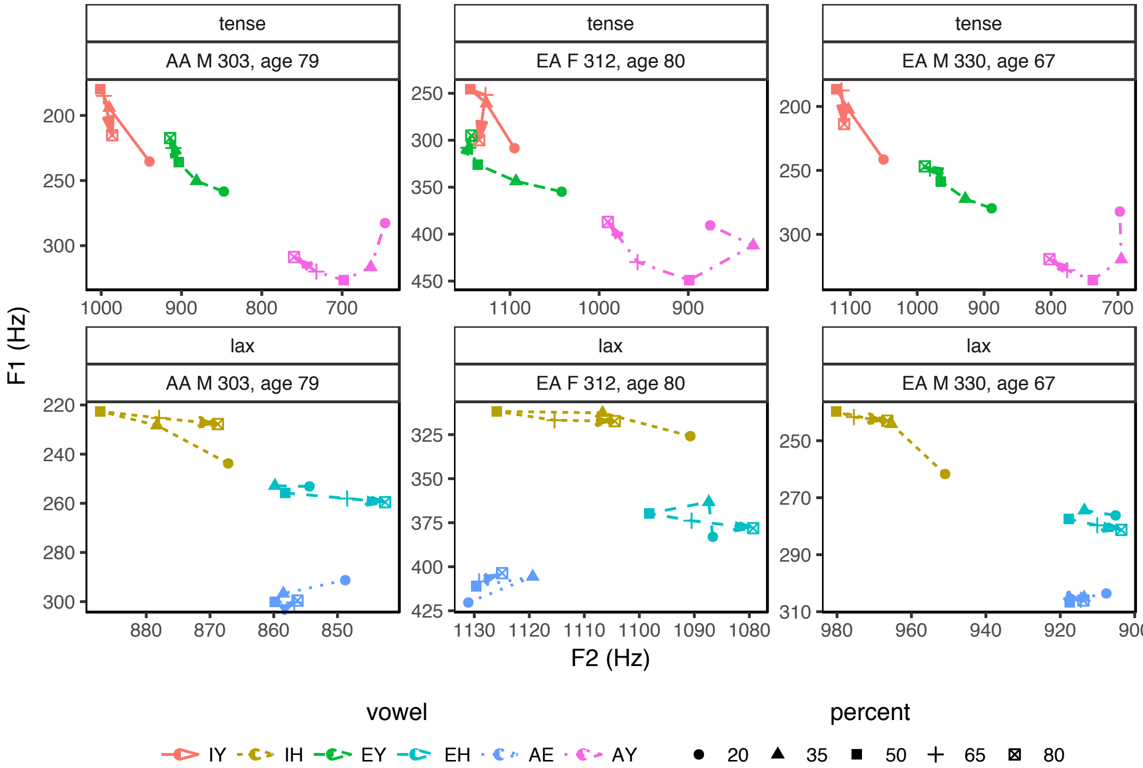

Figure 8. Trajectories for Tennessee

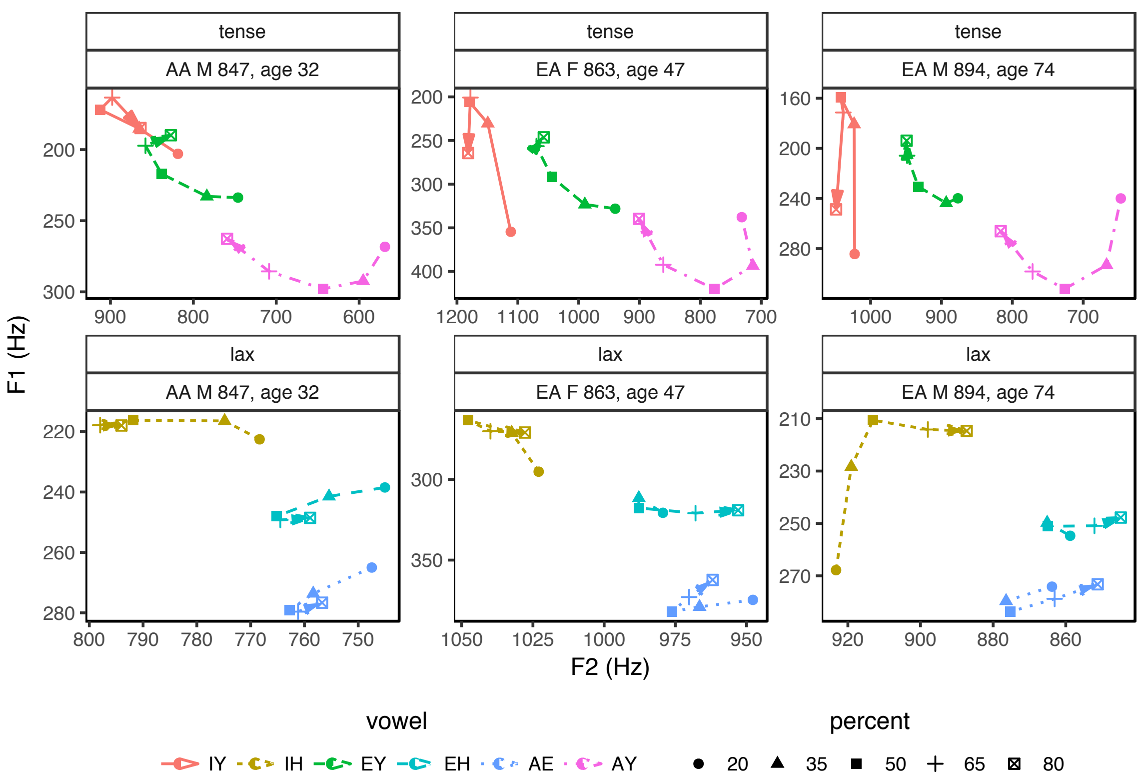

Figure 9. Trajectories for Texas

B. MONOPHTHONGIZATION OF /aɪ/

Monophthongization of /aɪ/ to [a:] is a noted aspect of Southern speech. What occurs in DASS? We anticipate that as monophthongization increases, and the front-vowel portion of the diphthong weakens, the angle of F2 over time will decrease. We predict, based on phonological descriptions, that monophthongization occurs primarily before (tautosyllabic) voiced sonorants, and less before voiceless consonants (Labov et al., 2006). Before voiced obstruents and in final position, descriptions vary. The formant angle of F2 was calculated for each token individually between the 20% and 80% time points, and is expressed here in radians, using calculations based on Fox & Jacewicz (2009). Because these calculations involve multiple time points per vowel, we use the time-course dataset.

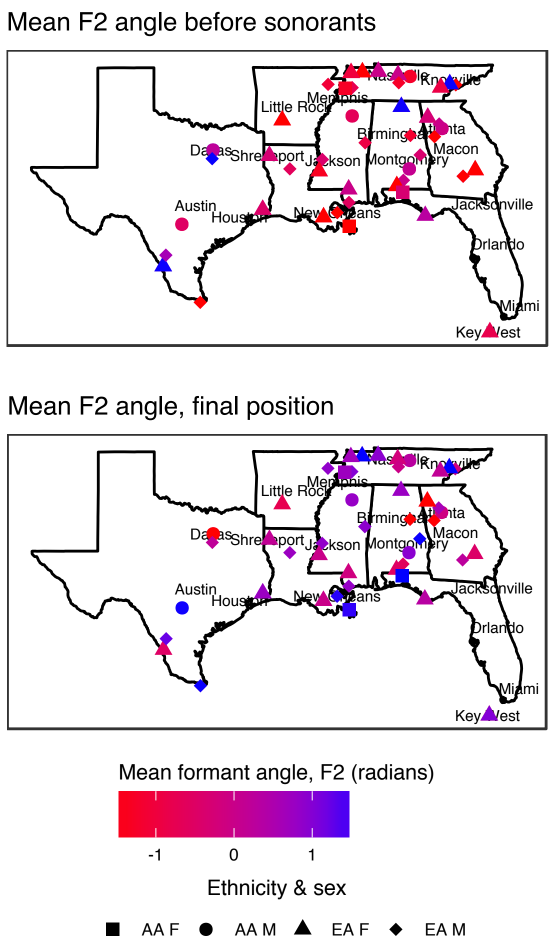

Figure 10. F2 angle before sonorants and in final position

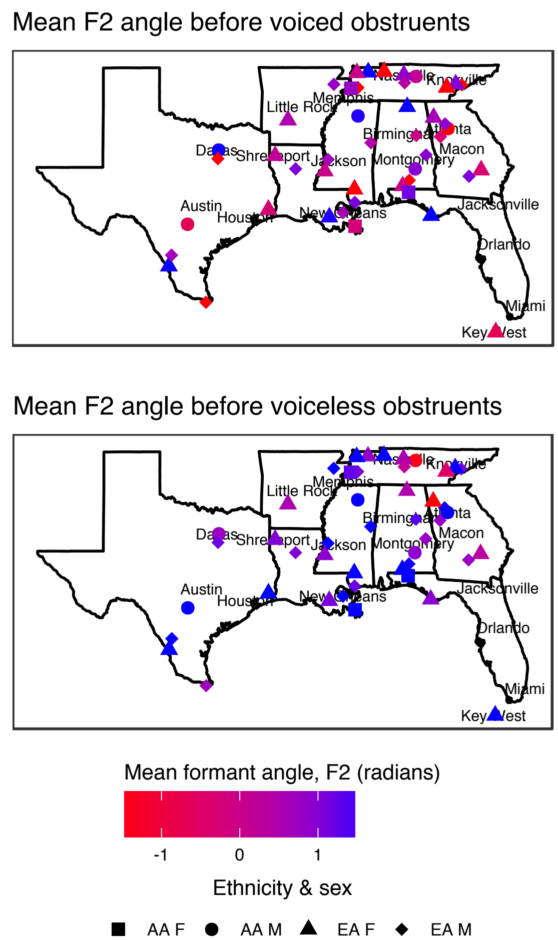

Figure 11. F2 angle before voiced obstruents and voiceless obstruents

For each speaker, in each of four phonological conditions, an average F2 angle is expressed in Figures 10 and 11 along a color scale, where red indicates a low angle (highly monophthongized) and blue indicates a high angle ([aɪ] retention). We find that monophthongization, broadly speaking, follows descriptive phonologically conditioned patterns: overall, speakers have the *lowest* F2 angles in pre-sonorant position, and the *highest* angles before voiceless obstruents. In final position and before voiced obstruents results are more mixed: some speakers have very high or low average angles, but many have intermediate (purple) angles, suggesting either partial or variable monophthongization. Some speakers appear to monophthongize in all contexts; this is most concentrated among speakers from Appalachia, particularly in central Tennessee. However, it is clear that this glide weakening is variably implemented across speakers and regions. We test for the robustness of cross-context patterns with a pairwise *t*-test with Bonferroni correction for multiple comparisons, and find that all differences are significant ($p < 0.001$) with the exception of the final vs. pre-voiced obstruent positions ($p = 1$). Future work will examine how these patterns vary according to sociolinguistic variables, and will test whether an implicational hierarchy of monophthongization holds across contexts.

6. CONCLUSION

To conclude, we have illustrated acoustic results from the Digital Archive of Southern Speech with regard to several dialectically characteristic aspects of vowels. The large and naturalistic nature of the data offers new perspective on speech from this region of the United States. We have shown using single-point data how regional vowel shifting, with a high degree of variability, is implemented in naturalistic speech. With regard to the SVS and AAVS, we show that /ɛ/ has higher nucleus than /eɪ/ for some speakers, consistent with shifting in these two patterns. Turning to time-course data, vowel trajectories show that dynamic differences are maintained between tense and lax vowels, confirming that these front-vowel categories do not merge. Results based on F2 formant angles confirm patterns of phonologically conditioned weakening of /aɪ/ to /a:/, with strong speaker variation. As transcription and alignment continue, this data set will grow to 64 speakers, permitting a more balanced historical sociophonetic analysis of this region than has previously been available. Interested readers may interact with the dataset within the Gazetteer of Southern Vowels (Stanley et al., 2017).

ACKNOWLEDGMENTS

This research is supported by NSF Grant BCS #1625680, as well as by the UGA Graduate School and by the American Dialect Society.

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