Analyzing complex vowel articulations from acoustic data

D. Sky Onosson
University of Victoria

Presentation

- Topic of study: Canadian Raising in Manitoba
  - research conducted as part of MA thesis (2010) at University of Manitoba
  - associated with Rob Hagiwara's (2006) *Winnipeg Vowels Project*
- Research question: how to extrapolate from acoustic data to articulation (*among others!*)
- Goal: develop a method which extracts crucial information on diphthong articulation — including *position, duration* and *velocity* — without being overly complex

CR in Manitoba

- Subjects and data:
  - 8 speakers: Manitoba-born, female, native English speakers, ages 24-34
  - wordlist task: elicitation of 200+ tokens per speaker of /aj/ in a variety of phonetic contexts, with contrasting voiced/voiceless codas
  - 1,600+ tokens of /aj/ in total
- Study of /aw/ remains for future research

Transcription of diphthongs

- Various sources differ in representation of CR diphthongs:
  [aj] ~ [aɪ], [aw] ~ [aʊ]
- Either choice might be justified on phonetic or phonological grounds, depending on how define the term "diphthong"
- Miret (1998): *diphthong* is not a well defined term:
  - Catford (1977): *"a sequence of two perceptually different vowel sounds in one and the same syllable"*
  - Ladefoged (1982): *"single vowels with continuously changing qualities"*

Monophthongs vs. diphthongs

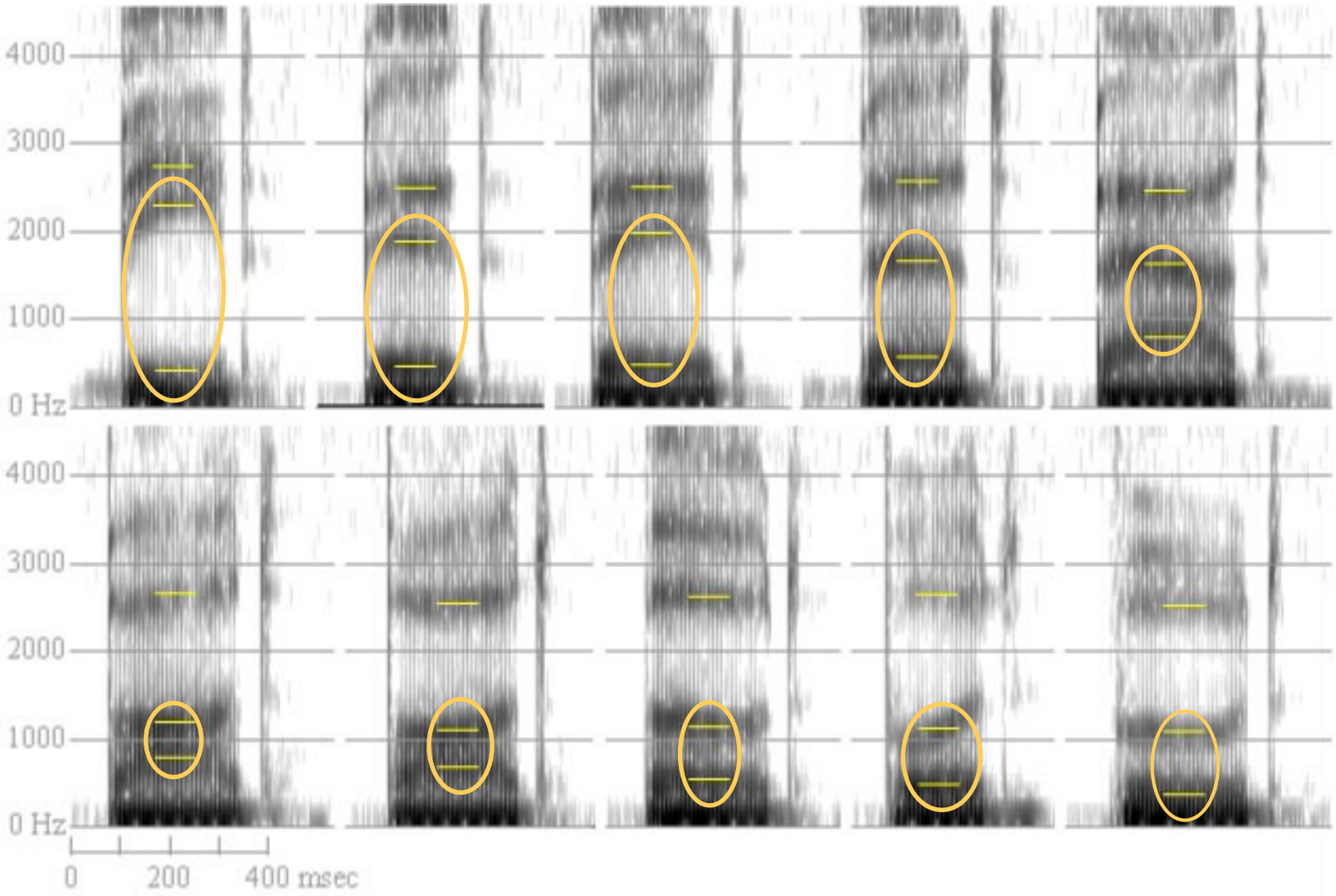
- Single or multiple articulations in sequence
- Absence or presence of articulatory *motion* and *trajectory*
  - Trajectory: "*The path of any body moving under the action of given forces*" (OED)
- Trajectories are *physical paths* — in this case, of speech articulators, e.g. the tongue — which can be extrapolated from acoustic data

Canadian Raising

- Martin Joos first described Canadian Raising in 1942:
- *"The Canadian diphthongs /aj, aw/ have higher initial tongue-position in pre-fortis context than elsewhere, while for all other syllabics* ***there is only a difference in length*** *in the two kinds of context."*
- Joos suggests CR arose from *"a shift from a difference essentially of length to a difference* ***essentially of quality****"*
- My research suggests that **length** is still highly significant — more so than quality; Canadian Raising is more a process of *shortening* than it a process of *raising*

Developing a method

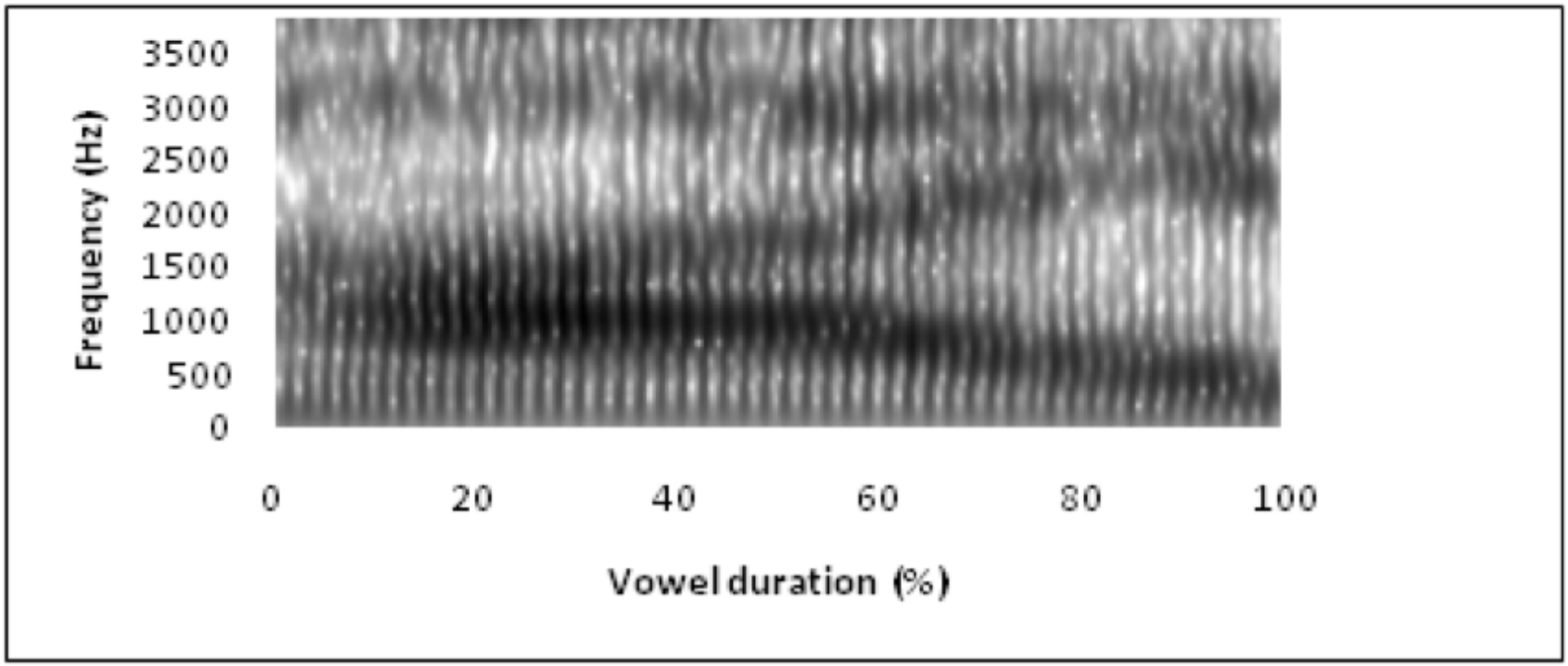
- CR is process of variation involving diphthongs
- Diphthongs involve an articulatory trajectory
- Given a different initial position (nucleus), each CR allophone/variant must have a different articulatory trajectory
- What is the best method to compare varying articulatory trajectories?



Monophthongs

Formants typically measured at a single point selected to represent vocalic nucleus

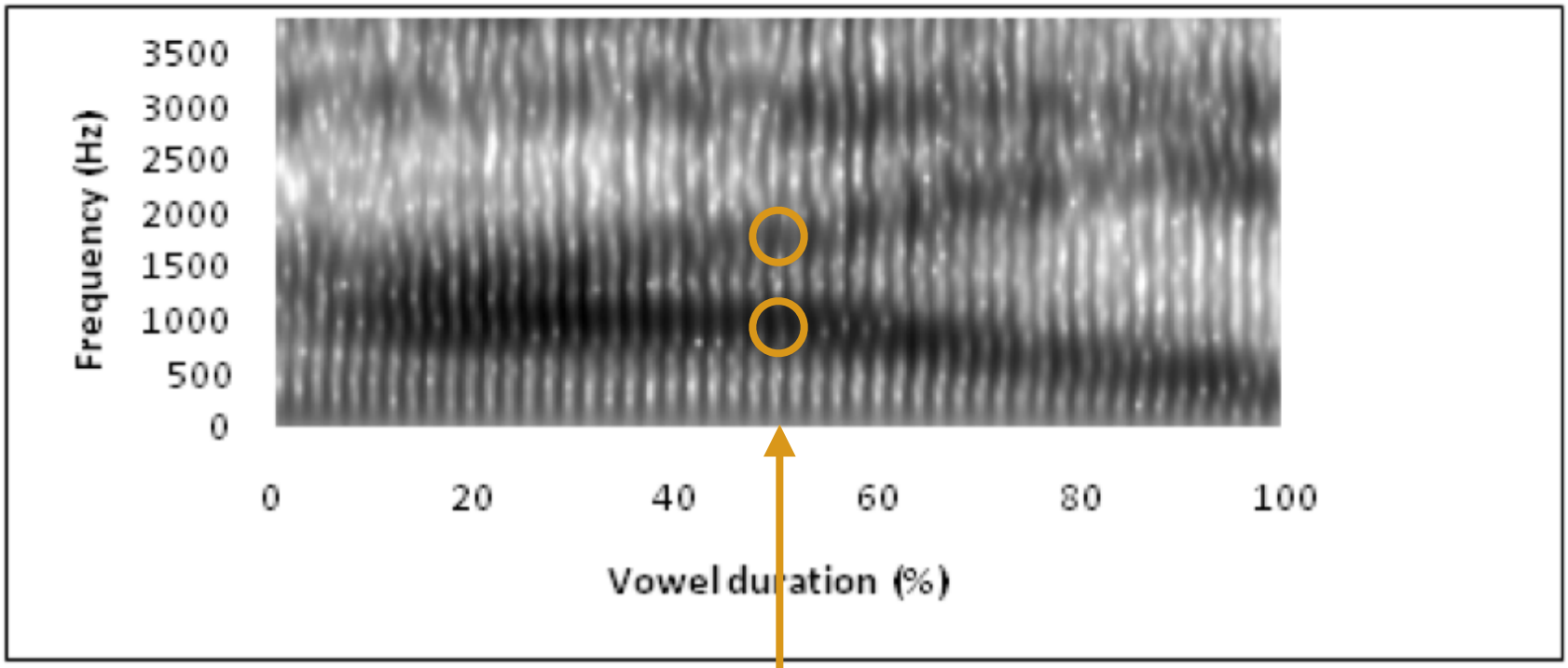
Image: Ladefoged (2001)



Diphthongs

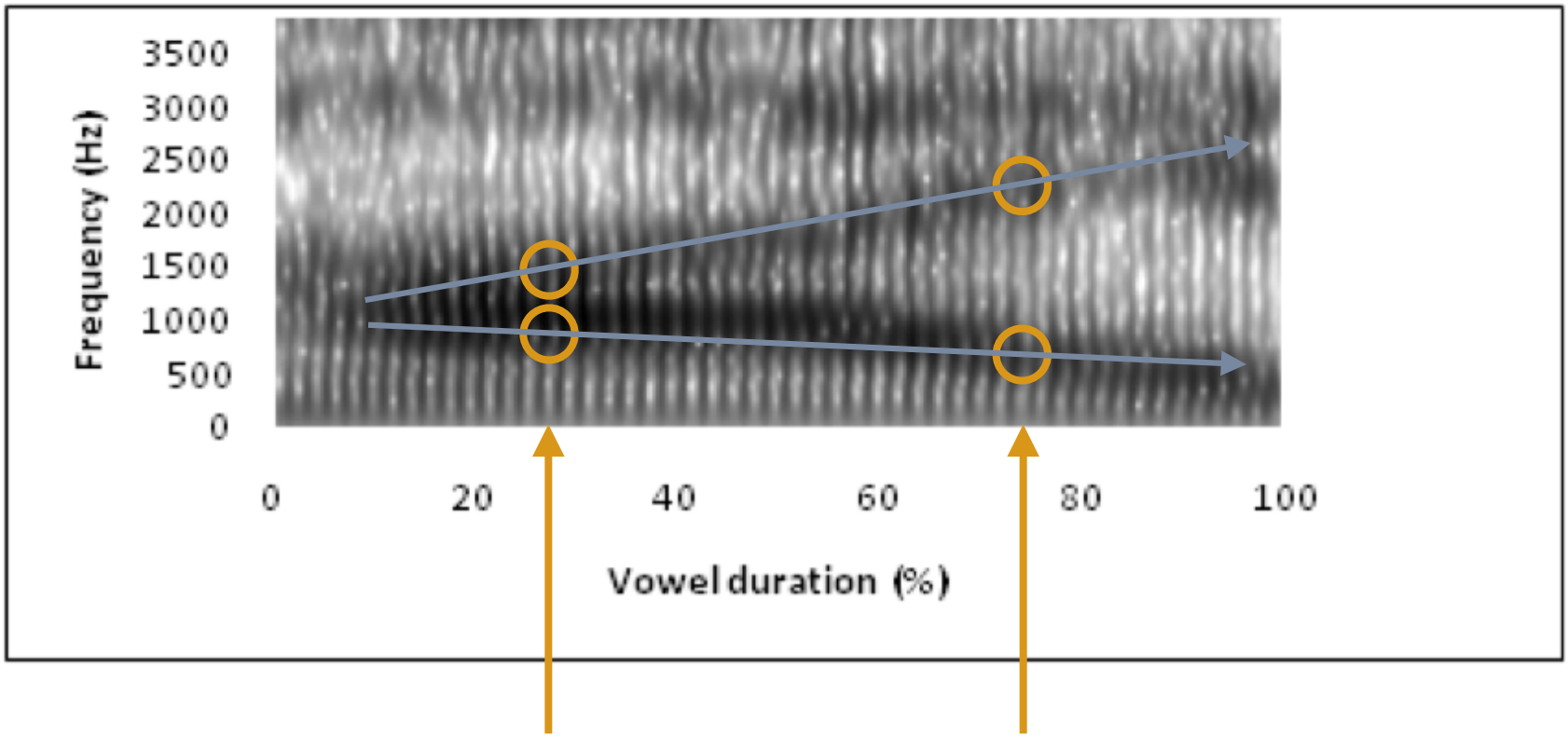
Where is the vocalic nucleus?

How many positions at which to measure formants?



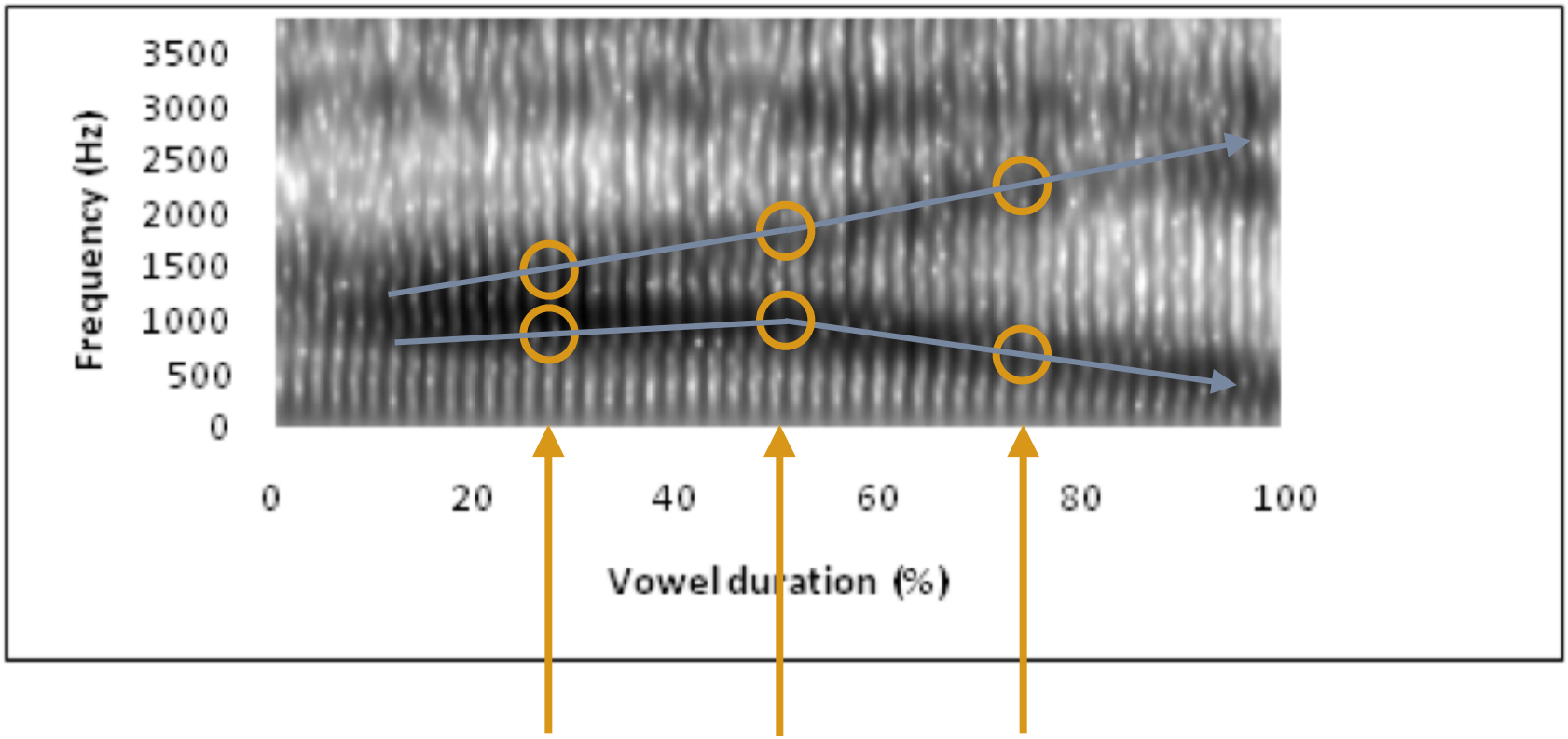
Diphthongs

Measuring at one position is clearly inadequate



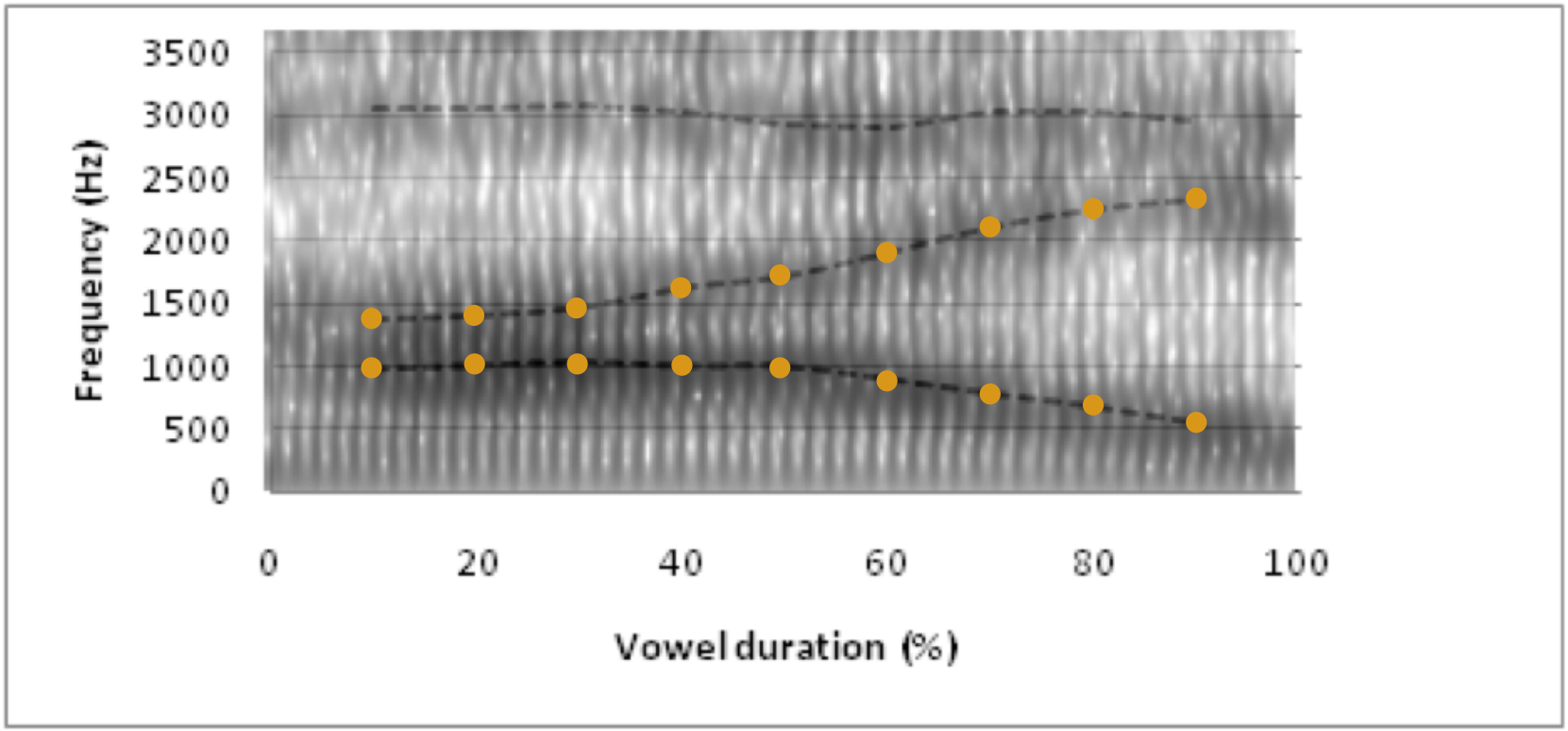
Diphthongs

Two timepoints: details of formant trajectory not preserved



Diphthongs

Adding a third point is a better representation — but some detail still missing



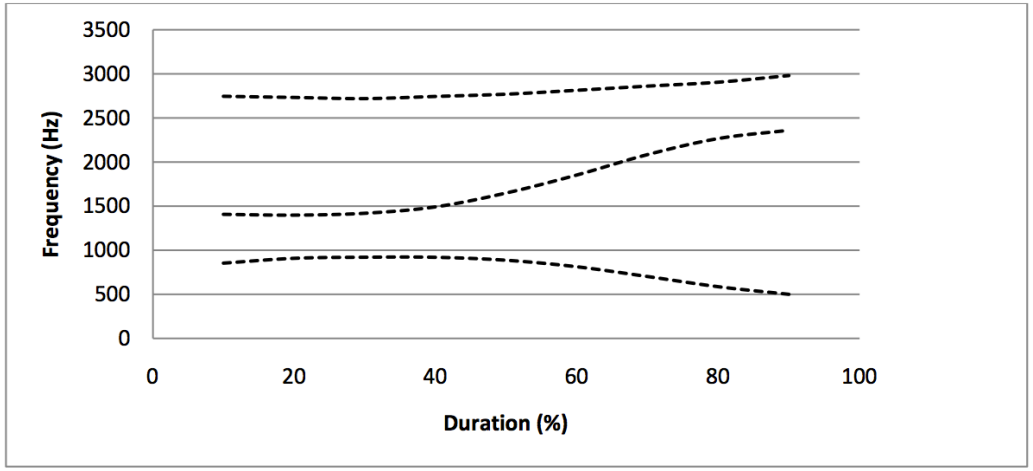
Multiple timepoints

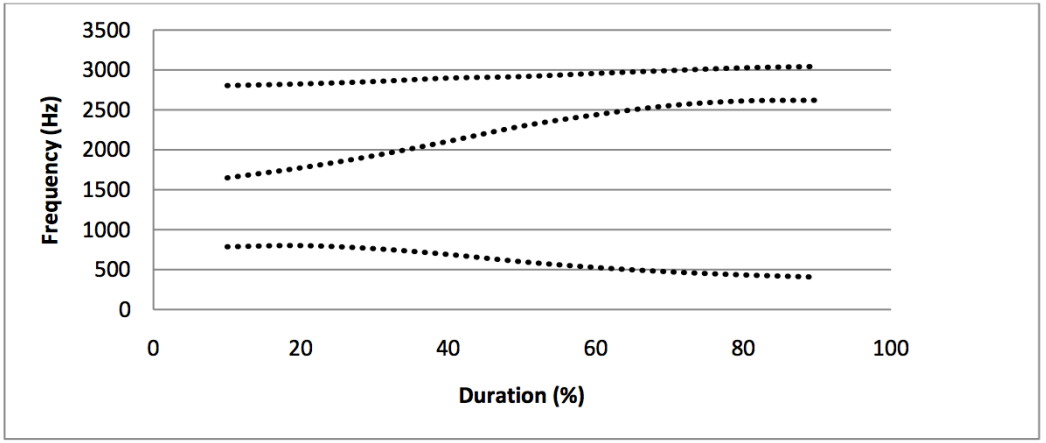
Graph of data from nine measurement points overlaid on spectrogram (i.e. formants measured every 10%)

Comparison of CR formants

- Formant values averaged across all speakers, tokens
- Use of percentile scale fails to indicate durational differences between allophones
- Formant values and trajectories appear visually very distinct

Non-Raised





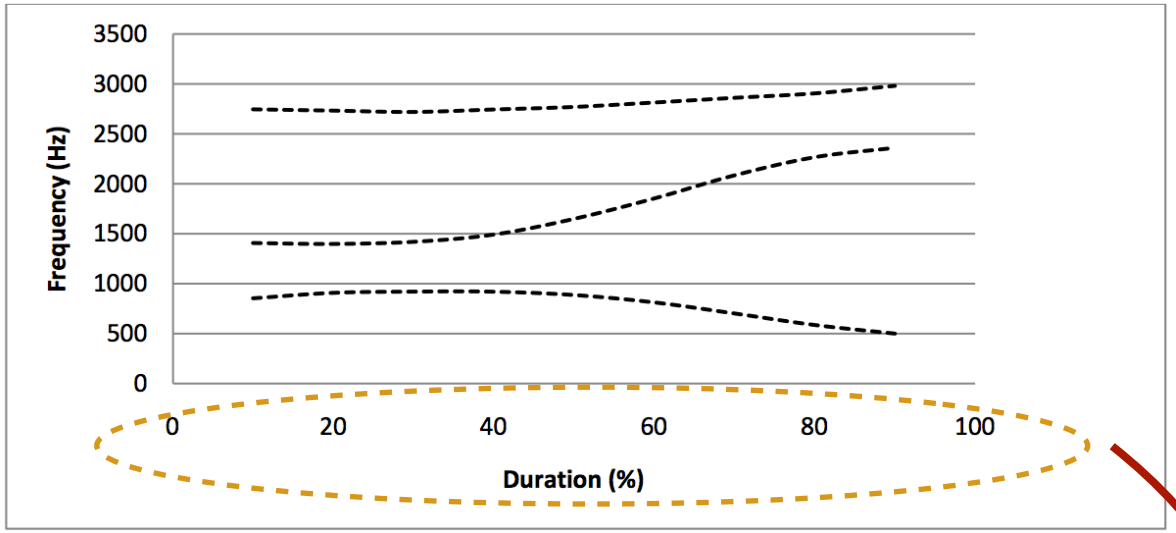
Raised

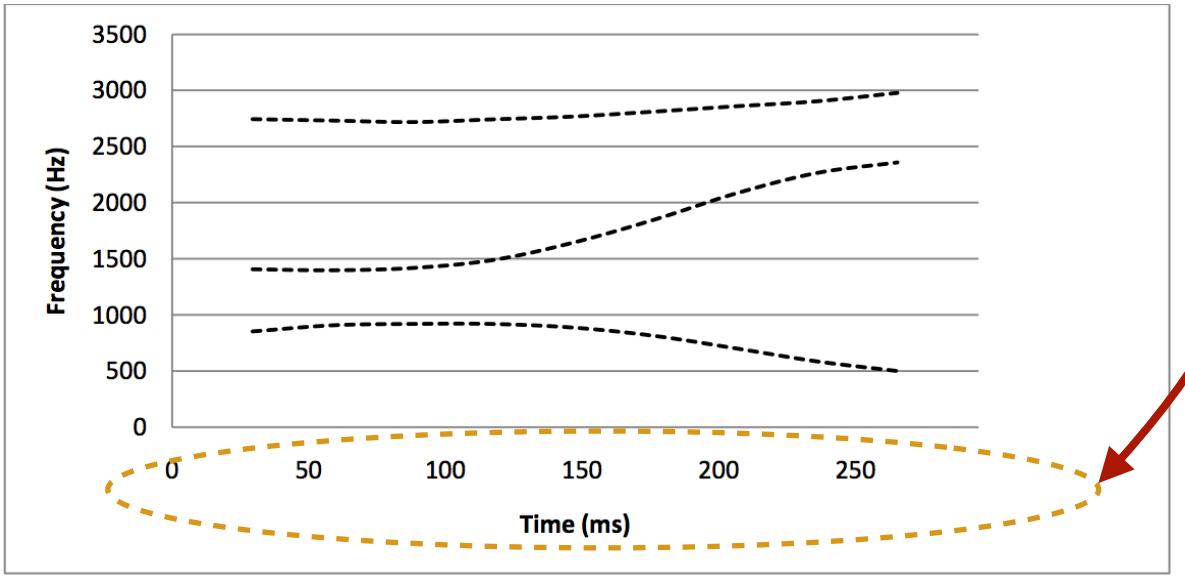
Durational differences

- CR allophones exhibit large differences in duration:
    - before voiced segment (*non-raised*) [aj]: 293 ms
    - before voiceless segment (*raised*) [ʌj]: 159 ms
    - **184%** difference in duration (alternatively, [ʌj] is **54%** shorter)
- Non-raising varieties of English: vowels before a voiceless coda shorter than in other contexts (Peterson & Lehiste 1960, Chen 1970, Umeda 1975…)
- Question: How to incorporate *duration* into comparison of CR variants?

Incorporating duration, non-raised allophone

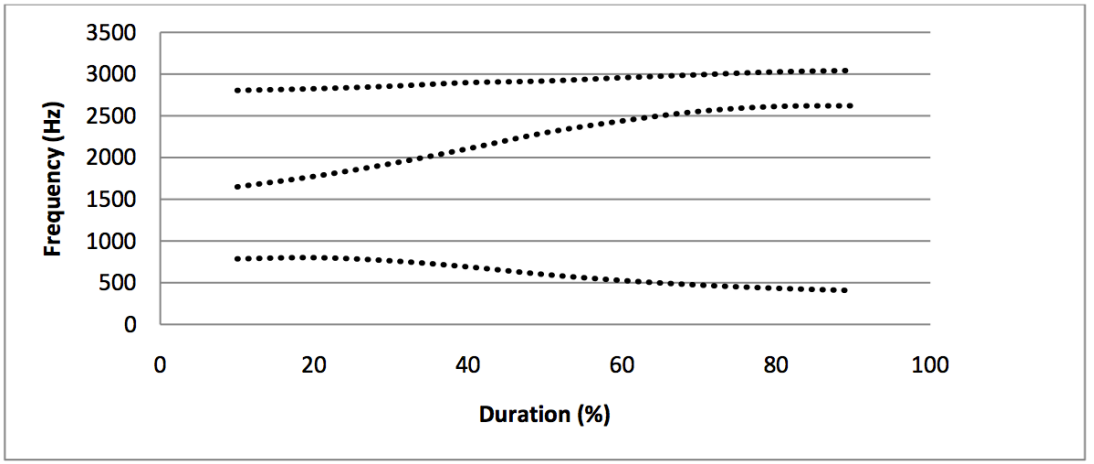
- Non-raised allophone is the longer variant, forms baseline for comparison
- Percentile timepoints recalculated as percentage of mean duration, 293 ms

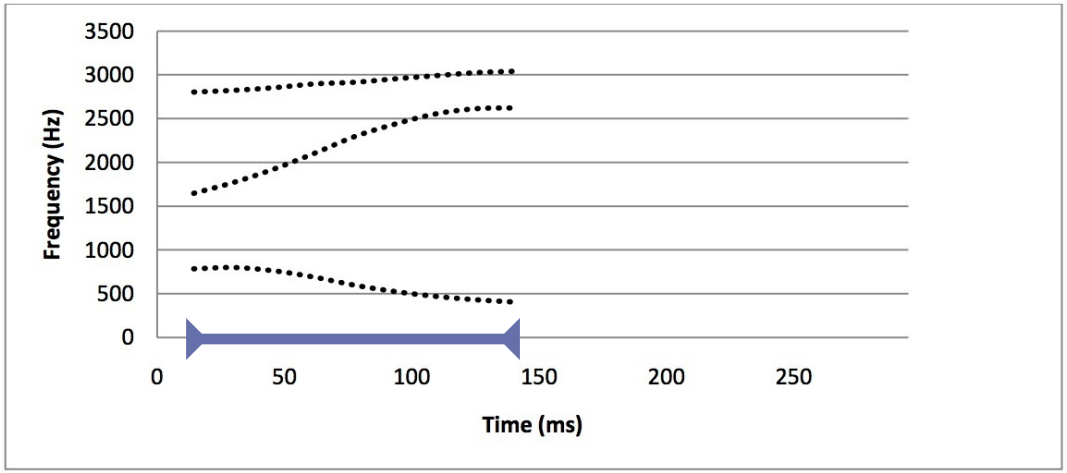




Incorporating duration, raised allophone

- Raised allophone percentile time scale recalculated to mean duration = 159 ms
- Time axis scaled to match non-raised duration baseline = 293 ms

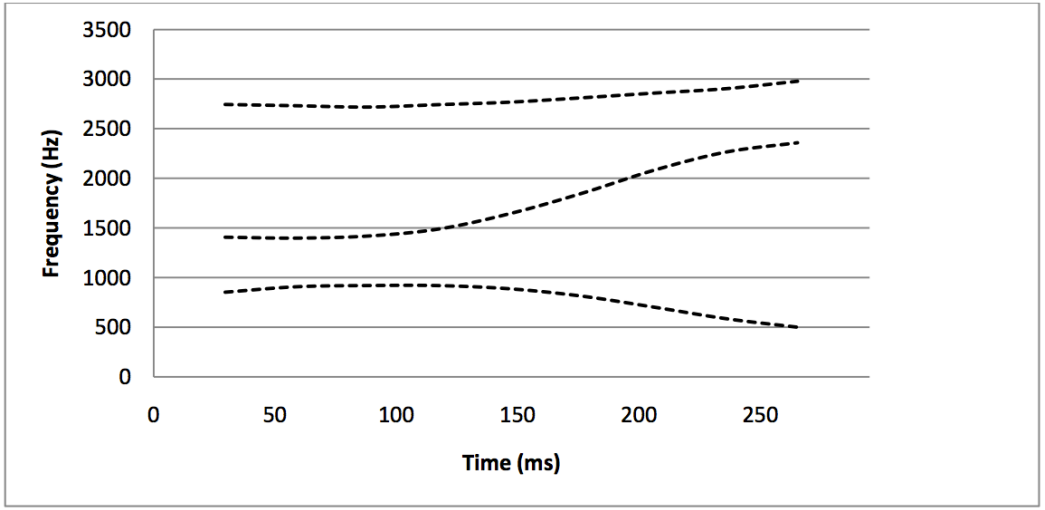


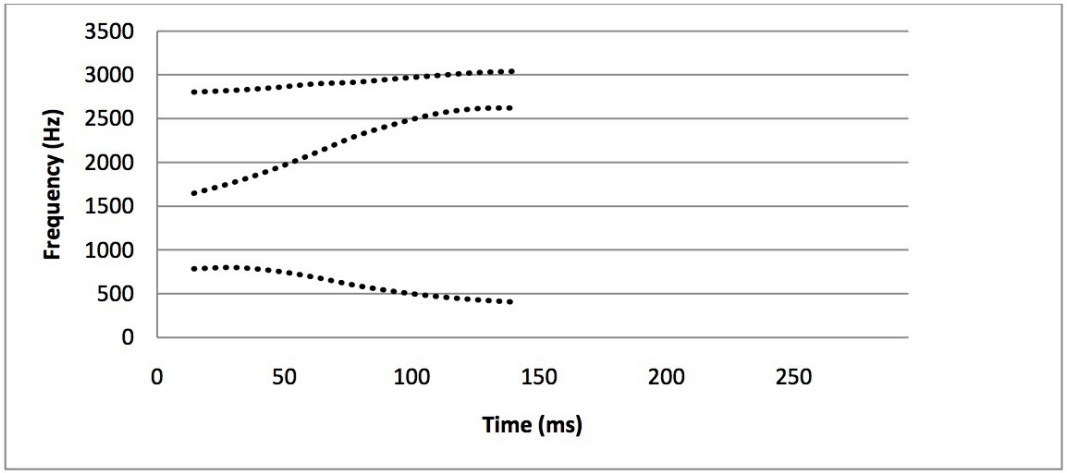


Incorporating duration, both allophones

- Comparison of both allophones aligned at left edge — articulatory *onset*

Non-Raised



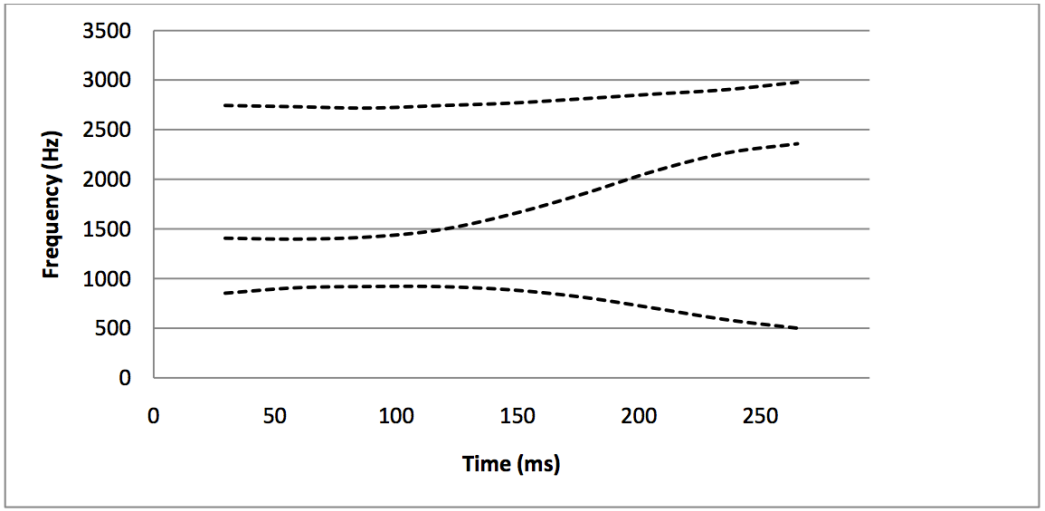


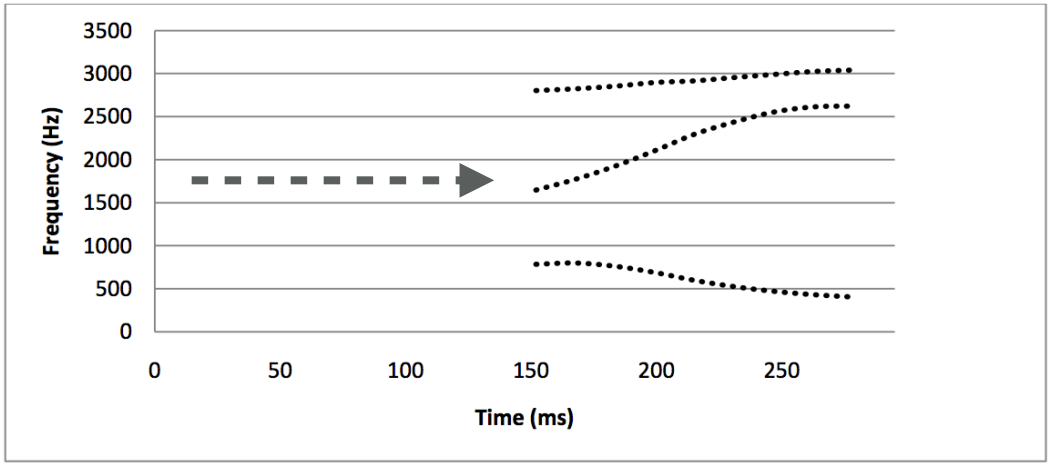
Raised

Incorporating duration, both allophones

- Raised allophone aligned to articulatory *offset* by shifting rightwards by the durational difference between two variants (136ms)

Non-Raised



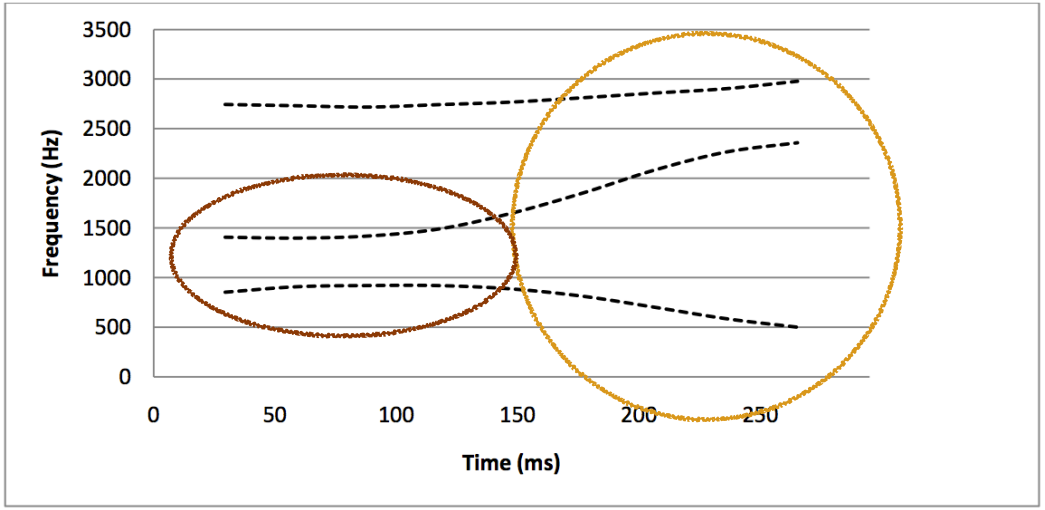


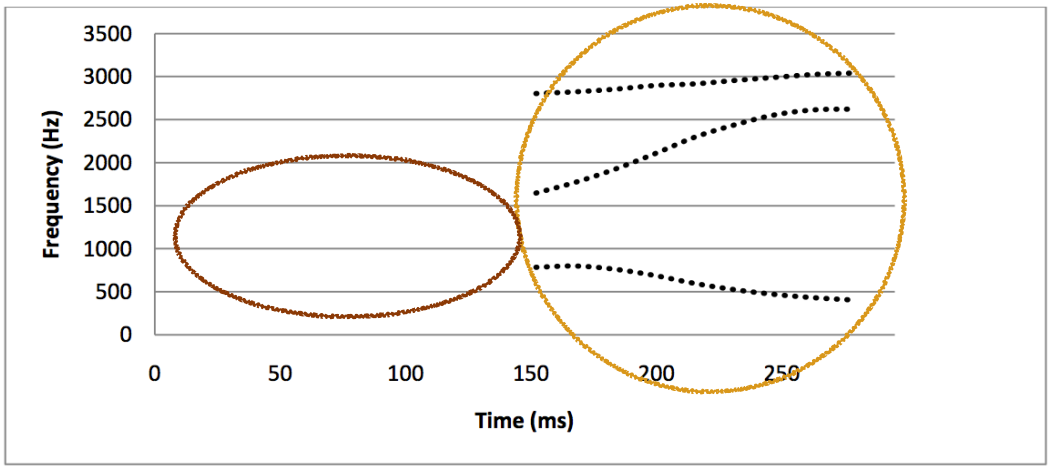
Raised

Incorporating duration

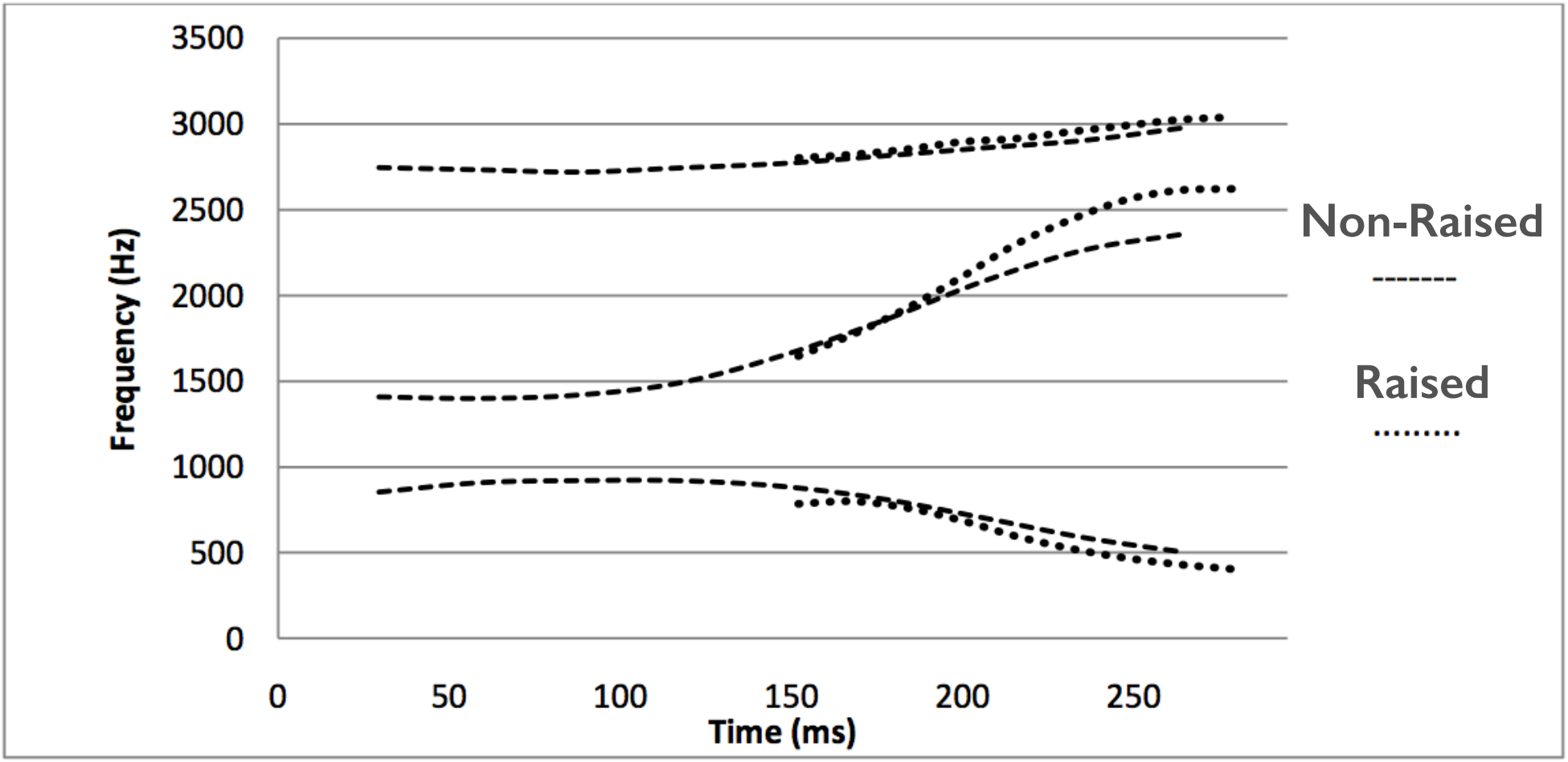
- Details of both articulatory trajectory and duration are well indicated
- Similarities can be observed between the two allophones which were not readily apparent prior to including durational information
- Non-obvious differences can also now be observed, i.e. presence/ absence of nuclear steady state

Non-Raised



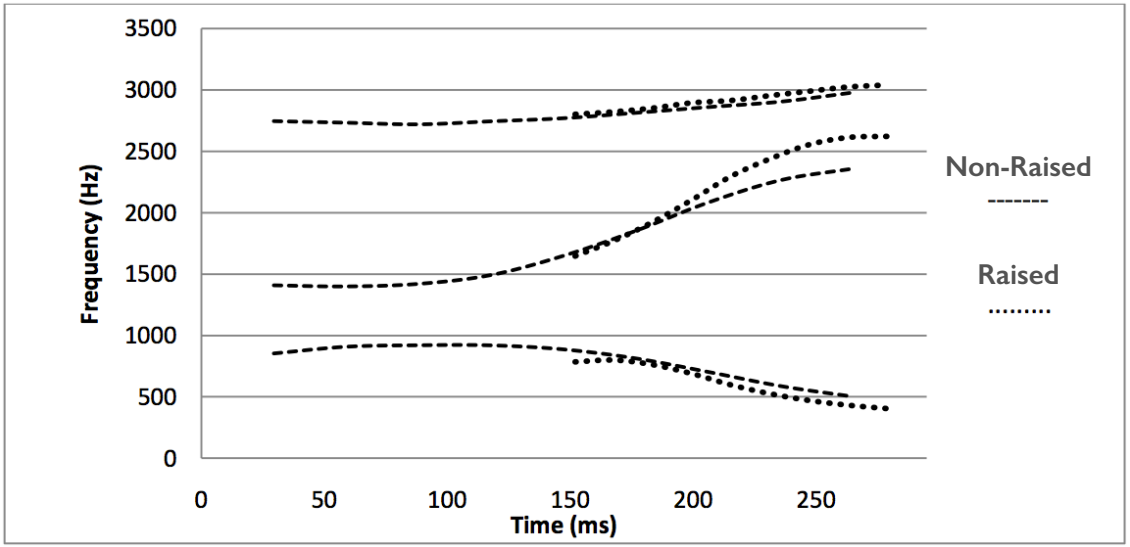


Raised



Canadian Raising

Redefining Canadian Raising



- **Raising** is slight, and evenly distributed *throughout* the articulation rather than occurring only at the nucleus
- **Fronting** appears to be even more significant; F2 is higher (*fronted*) in the raised allophone, and the difference *increases* over time
- **Shortening** of the raised allophone
- **Steady-state phase** comprises half of the *non-raised* allophone, almost entirely absent in *raised* allophone

Questions…

- How best to describe CR allophonic differences in terms of an articulatory model (e.g. *Articulatory Phonology*)? Are the duration and steady-state differences best accounted for as a single process, or multiple processes?
- What's going on with /aw/?
    - Chambers (1989) has suggested the two diphthongs are not necessarily part of a single phonological process as indicated by the occurrence of raising with only one of the diphthongs in some American dialects, e.g. Roberts (2007) in Vermont
- What's going on in other English dialects, which *don't* have raising but *do* have pre-voiceless shortening?
    - e.g. Thomas (2000) looked at /ai/ production in Ohio and Texas, pre-/d/ and pre-/t/ exhibit truncation at different edges of the articulation — pre-/d/ truncates the glide, pre-/t/ truncates the nuclear steady state, overall duration much less divergent
- Is this method applicable to studies of diphthongs in other languages?

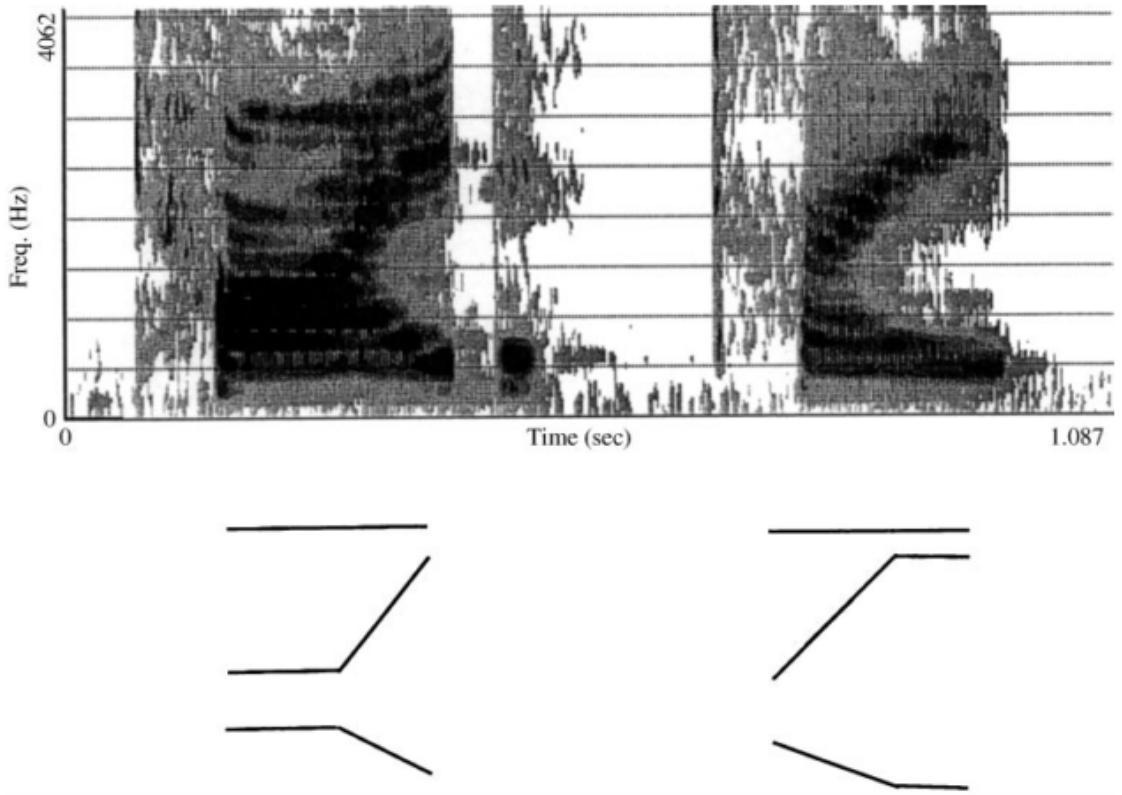
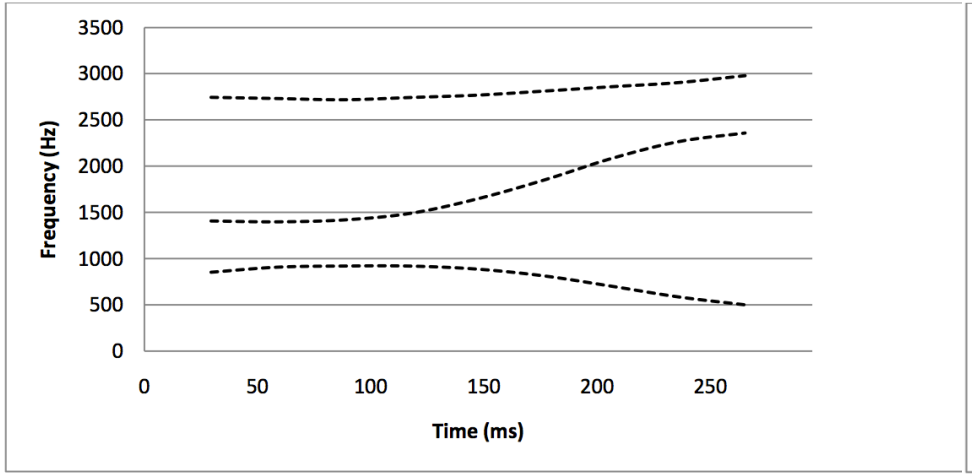
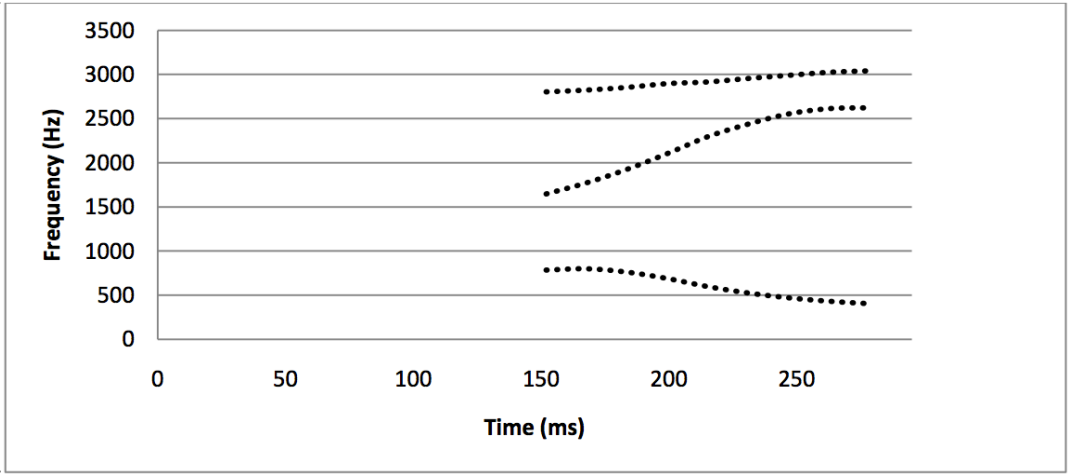


Figure 2. Spectrogram of *tide ... tight* uttered by a female speaker from Johnstown, with a schematic diagram of the first three formants.





References

- Catford, J. C. (1977). *Fundamental problems in phonetics*. Edinburgh: Edinburgh University Press.
- Chambers, J. K. (1989). Canadian Raising: Blocking, fronting, etc. *American Speech*, 64(1), 75–88.
- Chen, M. (1970). Vowel Length Variation as a Function of the Voicing of the Consonant Environment. *Phonetica*, 22(3), 129-159.
- Hagiwara, R. E. (2006). Vowel Production in Winnipeg. *The Canadian Journal of Linguistics*, 51(2), 127–141.
- Joos, M. (1942). A Phonological Dilemma in Canadian English. *Language*, 18(2), 141–144.
- Ladefoged, P. (2001). *A Course in Phonetics*, 5th ed. Boston: Thomson/Wadsworth.
- Peterson, G., & Lehiste, I. (1960). Duration of Syllable Nuclei in English. *The Journal of the Acoustical Society of America*, 32(6).
- Miret, F. S. (1998). Some reflections on the notion of diphthong. *Papers and Studies in Contrastive Linguistics*, 34, 27–51.
- Onosson, D. S. (2010). *Canadian Raising In Manitoba: Acoustic Effects Of Articulatory Phasing And Lexical Frequency*. MA Thesis. University of Manitoba.
- Roberts, J. (2007). Vermont lowering? Raising some questions about /ai/ and /au/ south of the Canadian border. *Language Variation and Change*, 19(02), 181–197.
- Thomas, E. R. (2000). Spectral differences in /ai/ offsets conditioned by voicing of the following consonant. *Journal of Phonetics*, 28, 1–25.
- Umeda, N. (1975). Vowel duration in American English. *Journal of the Acoustical Society of America*, 58(2), 434–445.