



Weather events in air traffic control standards and communication: discourse patterns and implications for language teaching and assessment

Eventos meteorológicos em normas e comunicações de controle de tráfego aéreo: padrões discursivos e implicações para o ensino e a avaliação de línguas

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Abstract: Weather events affect air traffic control (ATC) in many ways, for there are many situations that need to be reported in pilot-controller communication. This paper attempts to analyze the language used to express the impact of meteorological phenomena to air traffic operations, particularly in regard to aeronautical English, that is, the communication used during radiotelephony by air traffic controllers in training situations. For that, two types of analyses will be carried out: one regarding the formulaic structure of lexical units using 11 Aeronautical Meteorology terms within the ATC context (phase 1); and another one concerning the use of these terms by students in three ATC courses (for TWR, ACC and APP facilities) and how it affects their performance during communication activities in a learning environment (phase 2). These analyses will be based on rationales of lexical semantics for terminology; corpus linguistics (CL), comprising English for Specific Purposes (ESP) and learner corpora; and considerations about vocabulary assessment on aeronautical English exams. Results suggest that terminological patterns discussed in this paper show how meaning is dependent on

context, and how lexical semantic analysis of terms may contribute to reveal nuances of language used in a specialized context. In this way, it indicates courses have been efficient in teaching and practicing the use of the main meteorological terms related to aeronautical English and that, despite some mistakes students make, evidence points out that they are able to report weather conditions to pilots and to understand pilots' requests in a proficient level concerning vocabulary.

Keywords: meteorology; aeronautical English; terminology; learner corpus; language assessment.

Resumo: Eventos meteorológicos afetam o controle de tráfego aéreo (ATC) de diversas formas, dado que muitas situações precisam ser reportadas na comunicação entre piloto e controlador. Este artigo pretende analisar a linguagem utilizada para expressar o impacto de fenômenos meteorológicos para operações ATC, particularmente quanto ao uso de inglês aeronáutico, ou seja, a comunicação utilizada durante a radiotelefonia, por controladores em situações de aprendizagem. Para isso, duas análises foram realizadas: em relação à estrutura formulaica de unidades lexicais contendo 11 termos de Meteorologia Aeronáutica no contexto ATC (fase 1); e quanto ao uso desses termos por alunos de três cursos ATC (para os órgãos operacionais TWR, ACC e APP) e como isso afeta seu desempenho durante as atividades de comunicação em um ambiente de aprendizagem (fase 2). Essas análises serão fundamentadas nas teorias de semântica lexical para terminologia; linguística de corpus (LC), compreendendo Inglês para Fins Específicos (ESP) e corpora de aprendizes; e considerações sobre avaliação de vocabulário em exames de proficiência de inglês aeronáutico. Os resultados sugerem que os padrões terminológicos discutidos mostram como os significados dependem do contexto, e como a análise léxico-semântica de termos pode contribuir para revelar nuances da linguagem utilizada em contexto especializado. Desta forma, demonstrouse que os cursos foram eficientes no ensino e na prática do uso dos principais termos meteorológicos e que, apesar de alguns erros cometidos, as evidências apontam que os estudantes foram capazes de reportar condições meteorológicas e compreender as solicitações dos pilotos com nível de proficiência adequado em relação a vocabulário.

Palavras-chave: meteorologia; inglês aeronáutico; terminologia; corpus de aprendizes; avaliação de línguas.

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1 Introduction

The extent of weather events affecting air traffic control (ATC) is generally taken for granted, but it varies greatly, from the amount of

water film on the runway on a rainy day to volcanic ashes coming from another country as situations that need to be reported in pilot-controller communication. In this way, this paper attempts to analyze the language used to express the impact of meteorological phenomena to air traffic, particularly when it occurs in international traffic, and these professionals need to use English to communicate.

After a few fatal accidents which had communication problems as contributing factors, the International Civil Aviation Organization (ICAO) issued, in 2004 (with a reviewed second edition in 2010), the Manual of Language Proficiency Requirements, known as Doc 9835, in order to establish some parameters for English language proficiency, involving listening and speaking skills, for international pilots and air traffic controllers (hereafter, we will use the term ‘controllers’) who work in multilingual environments. According to this document, these professionals should be able to communicate through a highly specific code for aviation purposes, i.e. *aeronautical standard phraseology*,¹ and *plain language* whenever phraseology does not suffice to communicate in non-routine situations. The concepts of standard phraseology and plain language, which constitute the essence of the aeronautical English, are explained in Table 1, as follows:

TABLE 1 – Definitions of phraseology and plain English.

Term	Definition/Conceptualization
Phraseology (standard phraseology)	It is a code used by pilots and air traffic controllers, in a limited number of restrict and predictable communicative events characterized by short phrases and reduced vocabulary which allows a concise, precise and efficient transmission of information related to a flight.
Plain English, plain language	It is the use of the English language in radiotelephony communication that exceeds the use of standard phraseology, when it is not sufficient, but that should mirror phraseology, keeping its characteristics and specificities, as well as the same critical safety requirements such as intelligibility, non-ambiguity and concision.

Source: Adapted and translated from Scaramucci; Tosqui-Lucks; Damião (2018, p. 300).

¹ ICAO recommendations for the use of standard phraseology can be found in Doc 9432, Manual of Radiotelephony (ICAO, 2007) and Doc 4444, Air traffic management (ICAO, 2016).

By considering those definitions on phraseology and plain language, Tosqui-Lucks and Silva (2020a, 2020b) discuss the aeronautical English concept, explaining that controllers and pilots have to make crucial decisions, which require high levels of attention, focus and memory. Proficiency in a foreign language may pose major stress in those situations, due to interlinguistic aspects, different intercultural backgrounds, possible code-switching and other pragmatic issues (Cf. TOSQUI-LUCKS; SILVA, 2020a).

Concerning *plain English* as one of the elements of radiotelephony communications, it must be used according to the same parameters of conciseness, precision, objectivity, intelligibility and unambiguity that govern the use of phraseology (ICAO, 2010, p. 3-5), i.e., in no way having the connotation of English for use in common everyday situations (SCARAMUCCI, 2011), nor for use in other aviation contexts, which escape communication by radiotelephony.

In this sense, it is paramount to be aware of phraseological patterns in aeronautical language as well as making proper use of specialized terminology in air traffic control communication. Therefore, in an attempt to follow these recommendations, the Department of Airspace Control (DECEA), a military organization of the Brazilian Air Force, attributed to the Airspace Control Institute (ICEA), responsible for ongoing training of professional controllers, the mission to develop both aeronautical English courses and an aeronautical English test to make sure all controllers involved with international traffic have at least the minimum required proficiency level (PL) to ensure safety in Brazilian skies.

Thus, ICEA has been developing on-site courses and, since 2015, on-line courses too, aimed at professionals who work at the three different ATC facilities: tower (TWR), mainly responsible for landing and take-off; approach control (APP), in charge of operations when the aircraft are flying after take-off or preparing to land; and area control center (ACC), responsible for aircraft on cruising level. Professionals working at these three different facilities have specific characteristics, responsibilities and tasks to perform, addressed accordingly in the three online courses developed for each of them, as will be more detailed in the next sections of this paper.

Concerning development and application of the Aeronautical English exam for Brazilian Air Traffic Controllers (EPLIS),² ICEA follows ICAO guidelines, which prescribes 6 PL, from which PL 4 is the minimum required to operate internationally; and assesses six independent descriptors, i.e. structure, vocabulary, pronunciation, listening comprehension, fluency and interaction. In this paper, we will focus on the descriptor vocabulary, based on 11 selected terms related to meteorology as follows: (1) rain, (2) wind, (3) wind shear, (4) turbulence, (5) wake turbulence, (6) conditions, (7) lightning, (8) formation, (9) cloud, (10) fog, and (11) thunderstorm. In this way, discourse patterns in the context of weather events in air traffic control standards and communication, and their implications for language teaching will be analyzed.

To study discourse patterns in air traffic control standards, and language teaching implications in air traffic communication during learning activities, this paper is organized in the following way: presentation of the theoretical panorama comprising rationales of lexical semantics, corpus linguistics (CL), including ESP and learner corpora, and considerations about vocabulary assessment on aeronautical English exams; detailed methodology explaining the compilation process of the reference corpus and the learner corpus, and the methodology design; discussion of discourse patterns regarding weather events in air traffic control phraseology standards (phase 1), specifically addressing formulaic structure of lexical units using 11 Aeronautical Meteorology terms within the ATC context; discussion of weather events in air traffic control communication in the learner corpus, based on the use of these terms by students in three ATC courses (for TWR, ACC and APP facilities) and how it affects their performance during communication activities in a learning environment (phase 2). In the last section, we will consider some implications for Aeronautical English teaching and make suggestions for addressing the weather terms on courses.

² In Portuguese, EPLIS stands for *Exame de Proficiência em Inglês Aeronáutico do Sistema de Controle do Espaço Aéreo Brasileiro*.

2 Theoretical Foundation

2.1 Phraseological patterns: a lexical semantic approach to terminology

For the study of terminology, it is paramount to verify the patterns of language, as how they relate to other terms in a language. According to Hunston (2010, p. 158), “observing pattern involves identifying similarity and forming notional categories.” In this sense, a word or term with the same meaning may be considered to have a different pattern, as it related differently to other collocates or its cotext.

To exemplify this perspective, Hunston (2010) analyzes verbs in a corpus used in her research to identify objective-subjective nature based on collocates, arguments and cotext, and for the verb react, she lists eight patterns:

- (1) REACT followed by a subordinate clause indicating stimulus; [...]
- (2) REACT followed by the preposition to; [...]
- (3) REACT followed by an adverb and then by the preposition to; [...]
- (4) REACT followed by a to-infinitive clause indicating consequence; [...]
- (5) REACT followed by the preposition with answering the question ‘how?’, [...]
- (6) REACT followed by the preposition with answering the question ‘what?’, [...]
- (7) REACT followed by a full stop; [...]
- (8) Other lines:
 4 two-thirds of the radical pairs reacting (in a field of typically only [...])
 13 efforts you may find the magician reacting too early or late.
 Also bear in. (HUNSTON 2010, p.160.)

Along with this perspective, Sinclair (2008) advocates that phraseological study must stem from the analysis of collocates (coselection), and not lexical and grammatical structures alone. If they are treated independently, without considering a differentiated meaning when combined in a specific way (phrases), studying phraseologies would not be fruitful.

Sinclair expands this perspective by classifying analysis of meaning in three levels: (1) contextual settings, as studied by Firth, using cotext analysis; (2) phraseological, by analyzing collocational frameworks (Cf. RENOUF; SINCLAIR, 1991); and (3) lexical and grammatical, where the grammatical stance presupposes a pool of possible choices, in which abstract patterns underlie meaning, and the lexical stance detail lexical items according to the meaning they create.

The interdependence of elements, as cotext, is one of the main contributions of CL, since it enables analysis of how terms actually behave in a language, not considering them as “closed” structures. In fact, defining a term is always a very complex task, as there is no set standard that works for all situations. In the case of specialized fields, this issue is even more sensitive (Cf. FINATTO, 2001; PEIXOTO, 2020), as there is a traditional perspective based on an Aristotelian point of view that word senses could be devoid of subjectivity by attributing general content (genus) + specification (differentia). The problem is that such a clear-cut perspective does not work so smoothly in most contexts, as meanings are more related to the word environment, i.e., how words/terms relate to other lexical items around this main given term.

In this way, the main contribution of lexical semantics is that it relates the semantic content of words to other words and associations, named combinatorics. In the air traffic environment, for example, the term ‘conditions’, analyzed in this paper, may bear the same general content of “the possibility of a situation to happen”, but the way it relates to other collocates actually specializes this meaning. For example, ‘air traffic conditions’ is different from ‘meteorological conditions’: while the first one may refer to the general context from departure to take-off, including weather conditions and aircraft conditions, the second one is more related to weather phenomena such as clouds, snow or thunderstorm.

Since it relies on contextual variables, lexical semantics take into consideration concepts and relations ideally extracted from running text. In this way, relations between concepts may range greatly, and polysemy becomes an issue as it is more sensitive to precisely define the whole scope of a specific word definition.

When it comes to teaching specialized language, the need of standardization tends to be stressed, but it must consider language in context. In this sense, semantic labels intend to delineate the conceptual

structure from a relational perspective, not only a definitional one, so as to enable understanding variation as part of language concepts, not as deviation.

In the case of multiword expressions, they may also be considered terms, and, as a matter of fact, most entries in specialized dictionaries are multiword terms. In the analysis carried out in this paper, ‘wind shear escape’, for example, clearly has a more specific definition than ‘wind shear’ itself.

Considering polysemy as typical in language, as it entails variation, leads to the elimination of the useless concern of trying to have many clear-cut definitions to situations where only nuances apply. In addition to that, it addresses cases where interferences with general language may occur, i.e. “a lexical item can denote a concept in a specialized field and convey a different meaning in everyday situations” (L’HOMME, 2020, p. 81). This is the case with the term ‘fog’, which has specificities regarding the range of visibility, something that is not taken into account in everyday situations but is very relevant for the specialized context, as explained by Peixoto (in press) in the following excerpt:

Regarding ‘fog’ (FG), ‘haze’ (HZ) and ‘mist’ (BR), the classification depends on humidity and visibility issues. ‘Fog’ is reported when the air is at about 100 per cent humidity and the visibility is less than 1000 m [Cf. ICAO 2005], while ‘mist’ presents visibility ranging from 1000 m and 5000 m, and relative humidity above 90 per cent. [Cf. ICAO 2005]. On the other side, ‘haze’ are “extremely small particles invisible to the naked eye and sufficiently numerous to give the air an opalescent appearance [...], usually only a few thousand feet thick, but may extend upwards to 15,000 feet (4,600 meters) [...]” and visibility may vary “greatly, depending on whether the pilot is facing into or away from the sun” (FAA, 2016: 16-5). Concerning those categories, although “mist may be considered an intermediate between fog and haze” (ibidem), identifying those phenomena may be critical, as “there is no distinct line between any of these categories” (ibidem). In Portuguese, fog (FG), haze (HZ) and mist (BR) are translated as ‘nevoeiro’, ‘névoa seca’ e ‘névoa úmida’. (PEIXOTO, in press).

A relational perspective also allows for an enduring definition, as concepts may change in time, mainly due to our understanding of knowledge, and structural definitions may need updates. Within this context, the focus of the lexical semantic approach is comprehending where the terms are located in a language system, considering interrelations.

Errors are commonly the focus of linguistic analyses within a learning environment but finding regularities in the use of language contributes greatly as errors are not necessarily related to a very low level of proficiency. Ebeling and Hasselgård (2015) have shown learners from higher levels of proficiency make an equivalent number of mistakes mostly because they use more complex structures. In that sense, grammatical mistakes are more related to verbal structures which are not commonly used in language, and more varied lexical structures tend to work as a thermometer to measure the actual level of proficiency.

Based on findings by Nesselhauf (2005), Thewissen (2008) and Chen (2013), Ebeling and Hasselgård (2015) clarify that it is more important to analyze the type of error a learner makes, not only the quantity of errors. More sophisticated structures such as phrasal verbs are more error-prone than simple structures, yet phrasal verbs are mostly used by more advanced learners. As a result, Nesselhauf (2005) has noticed in her investigation that free combinations account for 25% of errors while collocations account for 40% of errors. Of course, this must take into account student background as well as personal effort of individuals in the learning process. As Meunier explains,

Individual differences typically include aptitude, motivation, identity issues, personality traits, type of working memory, socio-educational background, language proficiency in the mother tongue (L1) and other languages learnt, but also numerous aspects related to cognitive restructuring. (MEUNIER, 2015, p. 385.)

Meunier (2015) expands this perspective by resorting to Bartning and Forsberg's (2006) study, indicating that the use of prefabricated language is a more skilled capacity in comparison to the use of simple verbal morphology. In this sense, the students' abilities to actually develop more sophisticated proficiency depends greatly on the communicative style of learners, which we believe could also be nurtured by following certain strategies. In Meunier's words, "whilst verbal morphology

displays what they call a strict development (p.19), prefabricated language does not seem to follow such strict development and is more sensitive to input and to the communicative style of individual learners” (MEUNIER, 2015, p. 392)

To enable a more representative assessment of students’ proficiency based on language used by them, the analysis of collocational patterns may be more relevant, since it allows for a more contextual perspective, considering how words relate to each other to constitute meaning. Ebeling and Hasselgård (2015) enlighten us on the relevance of idiomatic phrasal constructs and explain that:

‘Collocation’ is defined as involving some degree of fixedness/restriction on the combinations of verb with noun. This definition separates collocations from free combinations, in which the verb and the noun combine without arbitrary restriction, and idioms, in which both verb and noun have lost their original meaning, or which can only be used with the idiomatic sense in restricted environments. (EBELING; HASSELGÅRD, 2015, p. 220).

When considering discourse patterns in a given specialized language, adjectives are specifically harder to be captured in a conceptual structure (Cf. L’HOMME, 2020) since their meanings may have subtleties which would only be understood when analyzed in context. In language learning, adjectives are also considered the most complex structure precisely due to their combinatorial nature, also comprising specific order in multiword expressions.

By considering this complex panorama of weather events affecting air traffic operations, discourse patterns were analyzed according to a lexical semantic approach for terminology, to assess semantic relations of Aeronautical Meteorology terms, based on a classification of semantic labels as described in Table 2.

TABLE 2 – Description of semantic labels

#	Label	Description
01	CHARACTERISTIC	It refers to the trait, quality or property of the meteorological condition. E.g. ‘cold ~’
02	CHARACTERISTIC / INTENSITY	It is a label which combines the labels characteristic and intensity.
03	DIMENSION	It refers to the size or dimension of the meteorological condition E.g. ‘small ~’
04	DURATION	It refers to the time elapsed since the beginning of the meteorological condition or continuously. E.g. ‘~ during the night’
05	EPISODE	It refers to an occurrence as an episode or instances of the meteorological condition. E.g. ‘~ registration’
06	EPISODE / INTENSITY	It is a label which combines the labels episode and intensity.
07	FORECAST	It refers to a forecast, observation or notification of a meteorological condition. E.g. ‘observed ~’
08	FORM	It refers to the objective form of the meteorological condition, generally of concrete nature. E.g. ‘~ pellets’
09	INFORMATION FACTOR	It refers to an information or data factor with the purpose of quantifying the meteorological condition in some way. E.g. ‘~ data’
10	INSTRUMENT	It refers to instruments or devices used to measure or forecast a meteorological condition. E.g. ‘~ sensors’
11	INTENSITY	It refers to the level of intensity of a meteorological condition, generally associated with another feature (label). E.g. ‘strong ~’
12	LAYOUT	It refers to the layout or arrangement of the meteorological condition in the overall scenario. E.g. ‘~ vertical profile’
13	LOCATION	It refers to the location where the meteorological condition takes place, which can range from a cardinal direction or a geographical position, to a city or an airport. E.g. ‘~ no aeroporto’ [‘~ at the airport’]

14	MANAGEMENT	It refers to procedures derived from decisions taken to manage problems E.g. ‘~ mitigation techniques’
15	MOVEMENT	It refers to movement or continuous occurrence of a meteorological condition. E.g. ‘blowing ~’
16	PARAMETER	It refers to a standard used as comparison within a framework of meteorological conditions. E.g. ‘minimum ~’
17	PHENOMENON	It refers to an occurrence which precisely characterizes the meteorological condition. E.g. ‘ <i>precipitação de ~</i> ’ [‘~ precipitation’]
18	REFERENCE	It refers to a standard used as spatial indication of a meteorological condition. E.g. ‘minimum height of ~’
19	RELATED TERM	It refers to another term which is semantically related to the term analyzed. E.g. ‘~ and precipitation’
20	TYPE	It refers to a meteorological condition of a particular kind, class or group. E.g. ‘surface ~’
21	TYPE / DIMENSION	It is a label which combines the labels type and dimension.
22	TYPE / INTENSITY	It is a label which combines the labels type and intensity.
23	UNIT OF MEASUREMENT	It refers to a unit of measurement used to indicate a physical quantity regarding the meteorological condition. E.g. ‘~ <i>em (200) hP</i> ’ [‘~ in (200) hP’]
24	VARIATION	It refers to a variable state of a meteorological condition. E.g. ‘~ gradient’

Source: Adapted from Peixoto; Pimentel (2020).

There are more labels in the original paper by Peixoto and Pimentel (2020), and some others may be created to address the semantic nature of additional terms, as it was the case of the label ‘management’, which represents the relational context of the term ‘~ mitigation techniques’, for example.

Such lexical semantic terminological research is best equipped with corpora resources because it enables words to be analyzed in context, identifying different forms of concept or meaning expression. In a specialized approach, corpus containing institutional documents is

a relevant contribution because it contains language and perspectives of experts in the field. The next section will address this theoretical issue more thoroughly.

2.2 Corpus Linguistics: English for Specific Purposes and learner corpora

Many authors attest the benefits of CL to research and teach vocabulary (BERBER-SARDINHA, 2011; SCHMITT, 2000; STEFANOWITSCH, 2020; TAGNIN, 2006; TOSQUI-LUCKS; PRADO, in press). According to Schmitt (2000), corpus evidence has shown two important things: (i) that a very limited number of high-frequency words do the bulk of the work in language, and it is crucial that students master them; and (ii) that words tend to collocate, that is, multiword strings seem to act as a single lexeme. In fact, the author says that a major direction in vocabulary studies today is “researching these multiword units through corpus evidence to establish their frequency and behavior” (SCHMITT, 2000, p. 89).

This is part of a move from lexis as individual words to be considered in isolation toward viewing them as integral parts of a larger discourse, and it is valid to general English and English for Specific Purposes (ESP) discourse too. In this matter, Stefanowitsch (2020, p. 215) complements that all corpora consist of orthographically represented language, and this makes it easy to retrieve word forms. To him, the focus on words is also due to the fact that the results of research using CL have proved that words (individually and in groups) are more interesting and show a more complex behavior than traditional, grammar-focused theories of language. As an example, we can consider the word ‘wind’, which has different uses and meanings depending on the impact it has for aircraft landing, and can be expressed in multiwords such as ‘crosswind’, ‘tailwind’, ‘downwind leg’, etc.

Still considering CL for teaching vocabulary, Berber-Sardinha (2011) states that most pedagogical tasks focus on concordances, and presents some text-centered and multi-genre alternatives. The author also highlights some areas that may deserve attention in the larger context of Brazilian educational CL. Some of them are represented in this study: more research about it on academic level, more integration with diverse areas, more application on educational contexts, more pedagogical materials and teaching resources based on corpora and more

integration with distance education. For the latter, Berber-Sardinha, in the above-mentioned work, says that both distance learning and CL are technological areas that can profit a lot if instructional designers learn more about CL tools.

Gavioli (2005) states that corpus work in ESP appears to match teachers' and learners' requirements particularly well, for corpus analysis highlights recurrent features of language. The possibility of having instruments to describe the routine aspects of ESP language is a key teaching issue in ESP courses, where the teacher is often split between the need to be both an expert in the foreign language and an expert in the specialized discipline. Corpora of specialized texts seem to be a very useful instrument in isolating and providing indications about key lexical, grammatical or textual issues to deal with in ESP classes. Creating corpora from specialized texts is relatively easy and inexpensive for most teachers who are familiar with computers, and analyzing such pools of texts with concordancing software may suggest relevant lexico-grammatical items and the way they are used to deal with in the ESP class and the way they are used (GAVIOLI, 2005, p. 5). The author also highlights the advantages of "home-made" corpora created *ad hoc* for some particular teaching or learning purpose, which is our case. Even though there is some criticism about using corpus for pedagogical reasons because of a possible "confusion between what is scientifically interesting and what is pedagogically useful" (GAVIOLI, 2005, p. 27), she supports data-based corpus analysis for English as a Foreign Language (EFL) teaching because it can help researchers and material designers in producing more authentic descriptions of language usage which, in their turn, may improve teaching and reference materials.

Tosqui-Lucks and Prado (in press) state that, for many years, vocabulary selection for course content was made intuitively by material designers. With the advent of CL, computational tools started to be used as a source of information for textbooks. In ESP areas, this is even less common, and only recently CL findings started to be used in aviation. The authors present a list of corpora of aviation and aeronautical English compiled internationally and results from studies with four different corpora compiled with international and Brazilian pilots and controllers, considering ESP and learner corpora.

Gilquin (2015) states that, like any corpus, the learner corpus is a collection of machine-readable authentic texts (which can be written or

be transcripts of spoken data) sampled to be representative of a particular language or language variety. What makes the learner corpus special is that it represents language as produced by foreign language learners; and what makes it different from the data used in earlier second language acquisition studies is that it seeks to be representative of this language variety. To tackle the issue of degree of naturalness when defining learner corpora, the author cites Granger's (2008, p.338) definition of learner corpora as "electronic collections of (near-) natural foreign or second language learner texts assembled according to explicit design criteria" suggesting that they may be comprised of texts that are not, strictly speaking, naturally occurring texts. This is because, especially for foreign language learners, the target language only fulfils a limited number of functions, most of which are restricted to the classroom context. To this matter, Römer (2004) adds that the problem of authenticity in English language teaching has been discussed for many years. To her, "what authenticity really means in a language teaching context, which different types of authenticity play a role and whether or not we want to teach authentic English to our pupils are highly controversial questions among linguists and didacticians" (RÖMER, 2004, p. 153).

Tagnin (2006) states that a learner corpus can provide useful data to detect specific difficulties of language learners and consequently inform the production of pedagogic material to address these problem areas. To the author, a learner corpus can provide useful data to detect such specific difficulties and consequently inform the production of pedagogic material to address these problematic areas, but one of the problems with textbooks used in Brazil for teaching a foreign language is that most are written by foreign authors unacquainted with Brazilian students' difficulties. Then, in an attempt to overcome possible limitations and fulfill specific needs of the Brazilian context, we have compiled a learner corpus, with productions from controllers during in-service distance learning training. The discussion of language patterns in this learner corpus will be based on guidelines for the vocabulary descriptor of language assessment, published by the International Civil Aviation Organization (ICAO), as discussed in the next section.

2.3 Considerations about vocabulary assessment on aeronautical English exams

The documents that guide aeronautical English teaching and assessment, according to ICAO regulations, are Doc 9835 (ICAO, 2010) and Circular 323 (ICAO, 2009).³ The first one defines aeronautical radiotelephony communications (Chapter 3) and provides guidance on language proficiency teaching and assessment for pilots and controllers (Chapter 7; Chapter 6), while the other complements it by presenting specific recommendations for course designs, both classroom-based and through distance learning. The mentioned Circular details the design and development of language courses emphasizes that language teachers should be trained to teach this very particular type of ESP and enumerates a few characteristics of aeronautical communication: it is essentially oral, with no visual cues, and employs a very specific vocabulary, as clear and unambiguous as possible, “because it involves risk management not only for pilots and ATCOs but for society at large” (TOSQUI-LUCKS; SILVA, 2020a, p. 3).

These documents reinforce that both teaching and assessment should be guided by ICAO Language Proficiency Rating Scale, Annex 1, Doc 9835 (ICAO, 2010), for speaking and listening proficiency only, according to six differentiating PL (being 1 the lowest, 6 the highest and 4 the minimum to be considered operational). There are recommendations for assessing the candidates holistically and analytically. Doc 9835 presents the following holistic descriptors:

Proficient speakers shall:

- a. communicate effectively in voice-only (telephone/radiotelephone) and in face-to-face situations;
- b. communicate on common, concrete and work-related topics with accuracy and clarity;
- c. use appropriate communicative strategies to exchange messages and to recognize and resolve misunderstandings (e.g. to check, confirm, or clarify information) in a general or work-related context;

³ In this paper, we are referring to the second edition of Doc 9835 (2010), which was revised and included a great part of Cir 318 (2009) about Aviation English assessment – but the first edition of Doc 9835 was published in 2004, thus, earlier than Cir 323 (2009).

- d. handle successfully and with relative ease the linguistic challenges presented by a complication or unexpected turn of events that occurs within the context of a routine work situation or communicative task with which they are otherwise familiar; and
- e. use a dialect or accent which is intelligible to the aeronautical community. (ICAO, 2010, Appendix I.)

As for the analytical assessment, there are band descriptors for pronunciation, structure, vocabulary, fluency, comprehension and interaction. Specifically about the category vocabulary, the analytical scale for PL4 states that:

TABLE 3 – ICAO rating scale vocabulary PL4

Vocabulary range and accuracy are usually sufficient to communicate effectively on common, concrete, and work related topics. Can often paraphrase successfully when lacking vocabulary in unusual or unexpected circumstances.

Source: ICAO (2010) Attachment A (our emphasis)

The same rating scale presents the following description for vocabulary PL3 (that is, not suitable for international traffic):

TABLE 4 – ICAO rating scale vocabulary PL3

Vocabulary range and accuracy are often sufficient to communicate on common, concrete, or work related topics but range is limited and the word choice often inappropriate. Is often unable to paraphrase successfully when lacking vocabulary..
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Source: ICAO (2010) Attachment A (our emphasis)

If we look at the description for PL2, i.e. “limited vocabulary range consisting only of isolated words and memorized phrases”, it is clear that this level of proficiency is far behind NP3.

So, comparing PL3 and PL4, it is possible to conclude that, concerning the vocabulary descriptors of the rating scale, what differentiates a controller PL3 and a PL4 is the ability to use the vocabulary to communicate effectively on common, concrete, and work-related topics in a *usually sufficient way, with appropriate lexical range and accuracy*. Another important aspect is the ability to *often paraphrase*

successfully when lacking vocabulary in unusual or unexpected circumstances. This distinction is not always so clear, for ‘usually’ and ‘often’ are sometimes difficult to measure during an interview, but it is crucial, considering that PL4 is allowed to operate with international traffic and PL3 is not – a high-stake decision with many important consequences – people’s lives, ultimately.

Römer (2017) questions the traditional separation between lexis and grammar on rating scales. The author claims that reasons for this separation come from a structuralist view of language testing researchers’ understanding of language proficiency. According to her:

More recent models of language ability, including the influential model of Bachman and Palmer (1996, 2010), continue this separation of lexis and syntax as distinct aspects of “grammatical knowledge”, separating these aspects of language ability from knowledge of language functions, which is subsumed under “pragmatic knowledge”. Based on this view of language, many influential rating scales in language testing have traditionally treated lexis and grammar separately. (RÖMER, 2017, p. 478).

On the other hand, Römer (2017) argues that recent integrative and functionally oriented approaches to language learning have a more holistic approach to language proficiency, considering lexico-grammatical knowledge as a single category. According to her, CL offers an important contribution to this view that the phrase, rather than the individual word, is the fundamental unit of language, and that a great deal of communication consists of fixed expressions that defy simple categorization into either vocabulary or grammar. This approach is beginning to be considered in the area of language assessment too. While a major problem with many rating scales is that their descriptors are not based on analyses of empirical linguistic evidence but come from intuitive judgments, “corpus studies of lexico-grammar provide such empirical evidence that may be useful in informing the development, validation, and use of rating scales for speaking assessment” (RÖMER, 2017, p. 478).

We share this view and believe that words have to be analyzed in context, so that different forms of concept or meaning expression can be identified, as we have discussed in this section, and seems to be unanimous in contemporary studies of lexical semantics, terminology, CL, teaching and assessment. We hope that this work can offer a small

contribution to spread this view to high-stakes speaking tests, as is the case of aeronautical English assessment.

Starting from weather situations considered extremely relevant to ATC or that could be problematic or cause confusion, presented in Doc 9835 (ICAO, 2010) and in the Reference Corpus, based on our experience in the teaching of aeronautical English for over 10 years, and also on data presented in research carried out by Tosqui-Lucks and Prado (in press), our procedure was to investigate the use of the 11 selected terms and their variations in the three subcorpora to analyze how these terms are used by students, considering the vocabulary descriptor of ICAO rating scale.

Thus, our approach to CL is predominantly corpus-based and data-informed, since we look for particular linguistic characteristics already pre-established in the corpora and analyze the data found to verify the occurrences, frequencies, concordances and relevant information to understand the phenomena (RAYSON, 2008). At other times, we also follow the data-driven approach, when, for example, we observe the most frequent words generated in the Wordlist tool, or even the words with wrong spelling, which can be an indication of a pronunciation problem (as in ‘mantein’, ‘turbulance’), vocabulary (as in ‘dicende’, ‘buid-up’) or even when the choice of words is wrong, as in the case of ‘approximation’ by ‘approach’ or ‘alternative’ by ‘alternate’, as we will explain later. In order to detect problems in the students’ production, we did not correct anything in the corpus, we kept the spellings exactly as in the original. This decision forced us to carefully analyze the occurrences to see whether or not the same word was written in different ways, as in the case of ‘condictions’, ‘wheather’, ‘confirme’, ‘intencions’. The details of the methodology are presented in the following section.

3 Methodology

As mentioned before, this paper has two phases: the first one, based on lexical semantics applied to terminology, to analyze formulaic structure of lexical units using Aeronautical Meteorology terms within the ATC context; and the second one, to analyze the use of these terms by students in three ATC courses (for TWR, ACC and APP facilities) and how it affects their performance during communication activities in a learning environment. For that, we selected some key aeronautical meteorology (AER MET) terms particularly used in ATC phraseology,

and studied their lexical semantic relations in a reference corpus of ATC international and Brazilian standards; and in a learner corpus of air traffic control communication in learning situations. The key terms were selected based on their relevance in the corpora, as related to ATC communication, and the following ones were extracted: (1) rain, (2) wind, (3) wind shear, (4) turbulence, (5) wake turbulence, (6) conditions, (7) lightning, (8) formation, (9) cloud, (10) fog, and (11) thunderstorm. It is important to highlight that the occurrence⁴ of those words are related to the relevance of some meteorological phenomena in air traffic situations applied to the Brazilian context, in terms of occurrence and frequency of some weather events.

The software used for corpora analysis is AntConc (ANTHONY, 2019), a freeware corpus analysis toolkit for concordancing and text analysis, chosen because its interface is simple, very user-friendly and provide adequate tools for the purposes of this paper. In addition to that, Anthony (2019) provides many downloadable guides and video tutorials on the software website that may guide unexperienced teachers into the basics of CL analysis. The software also enables the use of regular expression (REGEX) commands, as a way to extract terms which have spelling variation or are misspelled in the learner corpus, as in the case of variations ‘wind shear’ and ‘windshear’, and misspelled occurrences of ‘wind sheer’. In this way, we believe – and hope – that aeronautical English researchers and teachers can be inspired by our ideas and try to use a similar methodology to compile a learner corpus with the production of their own students.

The architecture of our corpora (reference corpus and learner corpus) is described in the table 5.

⁴ As our aim in this paper is analyzing discourse patterns concerning aeronautical meteorology terms used within the air traffic control context, ‘occurrence’ of terms refer to different instances of use of a term, i.e. the exact same instance of use was not counted as another occurrence. For example, in spite of the fact ‘heavy rain’ appears many times in the learner corpus, this was only considered one occurrence; but ‘moderate rain’, even though similar in structure, was considered another occurrence of the term ‘rain’.

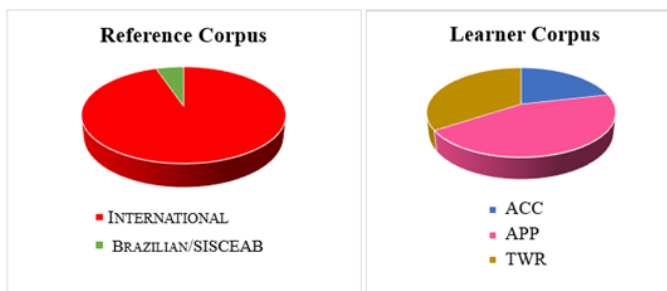
TABLE 5 – Corpora architecture (word types and word tokens)

CORPUS	SUBCORPUS	WORD TYPES	WORD TOKENS
REFERENCE CORPUS (ATC PHRASEOLOGY IN ENGLISH)	INTERNATIONAL	11119	581414
	BRAZILIAN/SISCEAB	3331	32202
LEARNER CORPUS (IN ENGLISH)	ACC	1052	13258
	APP	1763	27559
	TWR	1520	21249

Source: Authors’ own elaboration.

The proportion of each subcorpus in the corpora composition is best represented in the figure 1.

FIGURE 1 – Corpora Architecture (proportional comparison)



Source: Authors’ own elaboration.

As indicated in Table 5 and in Figure 1, the Reference Corpus is composed of ATC phraseology publications in English, set as standards by the international organizations ICAO, WMO and FAA, and by the Brazilian authority DECEA (SISCEAB system); and the Learner Corpus is composed of learning situations carried out during courses applied to the context of Area Control Center (ACC), Approach Control Center (ACC), and Tower (TWR).

The ATC phraseology publications compiled for the reference corpus are Doc 4444 (ICAO, 2016), Annex 3 (ICAO 2018), Doc 732 (WMO 2003), ORDER JO 7110.65W (UNITED STATES, 2015), MCA

100-16 (BRAZIL, 2018) and ICA 105-12 (BRAZIL, 2014). They were selected because they are guidelines which specifically address the use of phraseology within the ATC context, as published by official institutions dealing with aviation regulations also comprising meteorological instructions: the International Civil Aviation Organization (ICAO), the World Meteorological Organization (WMO), the Federal Aviation Administration (FAA, United States) and the Department of Airspace Control (DECEA, Brazil).

In this sense, Doc 4444 (ICAO, 2016) prescribes rules for Air Traffic Management; Annex 3 (ICAO, 2018) focuses on guidelines for the provision of Meteorological Service for International Air Navigation; Doc 732 (WMO, 2003) is a Guide to Practices for Meteorological Offices serving Aviation; Order JO 7110.65W (UNITED STATES, 2015) is an Air Traffic Organization Policy on phraseology and procedures; MCA 100-16 (BRAZIL, 2018) is the institutional documentation for ATC Phraseology within the Brazilian Airspace Control System (SISCEAB);⁵ and ICA 105-12 (BRAZIL, 2014) prescribes VOLMET Phraseology to be used in the SISCEAB system as well. As it can be visualized in Figure 1, the Brazilian/SISCEAB subcorpus is much shorter because it mostly comprises ATC phraseology used within Brazilian specific situations, by following standardized phraseology in English, originally prescribed by ICAO and WMO.

Regarding the learner corpus, it was compiled from evaluated activities that are part of a series of distance learning courses offered to Brazilian Controllers, called “Go4it”. There are three different courses: for area control center (ACC); approach control (APP) and tower (TWR). In each activity, the student must record an audio about the topics studied on that module, followed by the respective script. Since the activities were produced by students, it is only natural that they make mistakes. We opted for using the scripts with errors, not the versions corrected by the teachers, because the corrections could affect the results. So, we kept the problems with spelling, grammar or vocabulary. Considering that the courses have emphasis on speaking and not writing, some students do not worry too much about reviewing spelling mistakes on the scripts, because they will be graded mostly for their oral performance.

⁵ In Portuguese, SISCEAB stands for “Sistema de Controle do Espaço Aéreo Brasileiro”.

The three subcorpora used in the paper correspond to the scripts of the “Weather events” module of the three courses. The learners are in-service controllers, male or female, military or civil employees of Brazilian Air Force, enrolled in the courses offered from 2015 to 2018. Most of them have PL3 according to ICAO rating scale, but some have PL4 and need to revalidate their level, what occurs every 3 years.⁶

Each course lasts 8 weeks and comprises 8 modules, being the first one introductory (*Getting Started*) and seven of specific content: *Air Communication*, *ATC Jobs*, *Medical Emergencies*, *Parts of the Aircraft*, *Phases of Flight*, *Operational Events*, and *Weather en route*. Among the specific content modules, only five reproduce pilot-controller communications, and were compiled in the learner corpus: *Operational Events*, *Air communication*, *Phases of Flight*, *Medical Emergencies and Weather Events*. The other modules offer different kinds of oral activities, such as reporting a real situation or telling a story based on pictures. Having explained the compilation process of the three learner subcorpora, we will hereafter refer to it simply as “learner corpus” for the sake of this article, as contrasted to the “reference corpus”.

The compiled reference corpus was used in phase 1, and the learner corpus was used in phase 2; and the analysis focused on studying collocates (in the lexical semantics theory, it is called ‘combinatorics’) of each main term as listed according to a 3L-3R parameter, from which the first 50 ranked were analyzed. Then, we focused on left and right combinatorics of terms, and also associative patterns (relations), to proceed to a lexical semantic analysis (L’HOMME, 2020) by attributing semantic labels (PEIXOTO; PIMENTEL, 2020), and discourse patterns were discussed based on occurrences in the corpora. In addition to that, phase 2 approached language difficulties of learners, according to ICAO descriptors discussed in item 2.3 of this paper.

The methodology design for the work carried out in this paper is summarized in Table 6 as follows.

⁶ The learner corpus was compiled within an ATC military organization and its use is allowed only for previously authorized research, because of national safety reasons. In order to follow the recommended practices of the Committee on Publication Ethics, students signed a term of consent agreeing on the use of the data collected from their production within the course for research purposes, regarding that their identities are preserved.

TABLE 6 – Methodology Design

#	Activity	Description
01	Corpora compilation (reference corpus and learner corpus)	Compilation of publications on ATC phraseology comprising aeronautical meteorology situations, from official institutions (reference corpus) and from activities in a learning environment (learner corpus).
02	Extraction of key terms	Generation of wordlists and extraction of 11 terms related to weather situations which are critical for air traffic operations.
03	Analysis of discourse patterns in air traffic control phraseology standards (Phase 1)	Analysis of the formulaic structure of lexical units using 11 Aeronautical Meteorology terms within the ATC context, by studying left and right combinatorics of AER MET terms as appearing in the reference corpus.
04	Analysis of air traffic control communication in Aeronautical English courses (Phase 2)	Analysis of language structure as produced by students in classes of air traffic communication for Area Control Centers (ACC), Approach Control Centers (APP) and Towers (TWR), based on ICAO descriptor vocabulary of language assessment.

Source: Authors' own elaboration.

4 Weather events in air traffic control phraseology standards: discussion of discourse patterns

Meteorological conditions affect a varied range of air traffic control situations, related not only to en route events but also to air traffic operations particularly during landing/approach and take-off procedures. Runway conditions partly depend on meteorological conditions, especially when it comes to water effects leading to runway contamination, in addition to specific traits of the runway, which makes it more prone to water accumulation or not.⁷

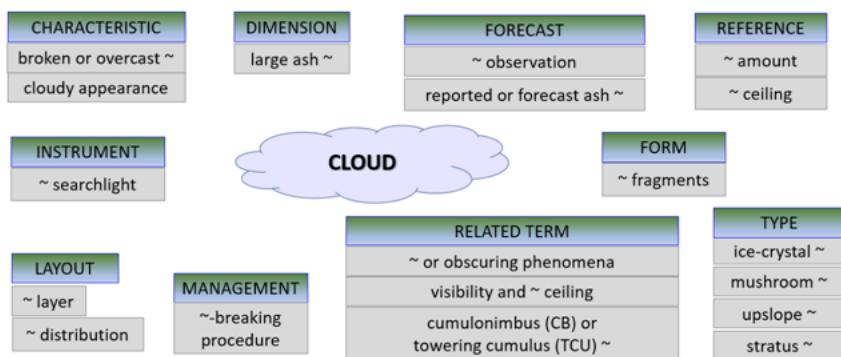
⁷ The International Civil Aviation Organization (ICAO) has recently issued some guidelines to address the types of runway contamination: the New Global Reporting Format (GRF) for Runway Surface Conditions (2019), based on the Takeoff and Landing Performance Assessment (TALPA) model issued by the Federal Aviation Administration (FAA) in 2016. ICAO Member States were demanded to implement the GRF grid assessment by November 2020; however, due to the COVID-19 pandemics, the deadline was postponed to November 2021. More information on GRF guidelines can be found at <<https://www.icao.int/safety/Pages/GRF.aspx>>.

By considering this holistic panorama, the WMO (2003) classifies possible aviation hazards as: **(a) in-flight hazards** such as icing, turbulence, lightning and volcanic ashes; **(b) hazards in the phases of approach and take-off**, including wind shear effects, turbulence, convective activity and freezing precipitation on aircraft; **(c) weather hazards affecting the acceptance capability of hub airports**, considering capacity for de-icing, and runway and apron snow clearance; **(d) weather hazards affecting the capacity of air routes**, such as mesoscale convective systems, volcanic ash and severe turbulence; and **(e) weather hazards affecting ground operations, passenger ground transportation and safety**, resulting from lightning, strong winds or hail, for example. In this sense, the Annex 3 (ICAO, 2018, p. 4-5) mentions that minimum present weather phenomena to be identified at airports, to enable safety of operations, are “rain, drizzle, snow and freezing precipitation (including intensity thereof), haze, mist, fog, freezing fog and thunderstorms (including thunderstorms in the vicinity).”

By considering this complex panorama of weather events affecting air traffic operations, discourse patterns were analyzed by following the lexical semantic approach discussed in item 2.1.

To illustrate how labels were attributed to collocates of a term, Figure 2 presents the semantic profile of the term ‘cloud’, by showing lexical semantic occurrences with this term and their respective semantic labels.

FIGURE 2 – Semantic profile of the term ‘cloud’



CLOUD – A cloud is a visible accumulation of minute water droplets and/or ice particles in the atmosphere above the Earth’s surface. Cloud differs from ground fog, fog, or ice fog only in that the latter are, by definition, in contact with the Earth’s surface. (UNITED STATES, 2015)

Source: Authors’ own elaboration.

In the reference corpus, the definition for ‘cloud’ was found in Order JO 7110.65W (UNITED STATES, 2015), in the glossary listed at the end, as well as definitions of two other selected terms, described in the following way:

WAKE TURBULENCE – Phenomena resulting from the passage of an aircraft through the atmosphere. The term includes vortices, thrust stream turbulence, jet blast, jet wash, propeller wash, and rotor wash both on the ground and in the air.

WIND SHEAR – A change in wind speed and/or wind direction in a short distance resulting in a tearing or shearing effect. It can exist in a horizontal or vertical direction and occasionally in both

CLOUD – A cloud is a visible accumulation of minute water droplets and/or ice particles in the atmosphere above the Earth’s surface. Cloud differs from ground fog, fog, or ice fog only in that the latter are, by definition, in contact with the Earth’s surface. (UNITED STATES, 2015).

Concerning ‘wind shear’, there was another related term (‘wind shear escape’), with a more specific meaning:

WIND SHEAR ESCAPE – an unplanned abortive maneuver initiated by the pilot in command (PIC) as a result of onboard cockpit systems. Wind shear escapes are characterized by maximum thrust climbs in the low altitude terminal environment until wind shear conditions are no longer detected. (UNITED STATES, 2015).

However, occurrences for ‘wind shear escape’ were not so prolific, as the only collocates found were ‘~ complete’, ‘~ maneuver’, and ‘~ procedures’, so ‘wind shear escape’ was not classified independently.

Regarding the profile of semantic labels for each term, Table 7 shows the total of lexical semantic occurrences and the total of labels, and also compares the semantic density of the selected terms, by calculating the total of labels per total of occurrences.

TABLE 7 – Profile of semantic labels for each term in the reference corpus

Term	Total of occurrences	Total of labels	Semantic density
rain	11	4	36%
wind	22	9	41%
wind shear	15	5	33%
turbulence	22	7	32%
wake turbulence	18	8	44%
conditions	24	8	33%
lightning	6	3	50%
formation	4	3	75%
cloud	55	10	18%
fog	17	5	29%
thunderstorm	11	5	45%

Source: Authors' own elaboration.

The occurrences of the selected terms often come as ‘ADJECTIVE + TERM’ or ‘NOUN + of + TERM’ / ‘TERM + of + NOUN’ (perception of ~; possible effects of ~; ~ of great vertical extent; ~ of operational significance) or adverbial structures such as ‘~ around the periphery of an airport’. In addition to that, it is interesting to note there were some few hyphenated constructions such as ‘~-breaking procedure’ and ‘~-prone areas’; and there were also passive structures such as ‘partially covered by ~’ and ‘algorithmically derived ~ warnings’, ‘~ networks to ATS’.

When it comes to the productivity of semantic labels, RELATED TERMS are the most common, with 82 occurrences, then TYPE and LAYOUT, with 23 and 22 occurrences. The labels DURATION, INTENSITY and MOVEMENT only had one occurrence each. The most diverse terms were ‘formation’ and ‘lightning’, accounting for 75% and 50% of semantic density, respectively. And ‘cloud’ and ‘fog’ are the most uniform terms, i.e., with less semantic variation, of only 18% and 29% respectively.

However, in the case of ‘cloud’, there were many occurrences of the semantic label TYPE (9), REFERENCE (7) and LAYOUT (7), of more objective nature. ‘Fog’ also had a more objective standard, with prevalent occurrences of CHARACTERISTIC (3) and LAYOUT (3) too. Regarding ‘lightning’ and ‘formation’, with more density, ‘formation’ has a more objective profile (TYPE semantic label is prevalent) while ‘lightning’

showed a more procedural perspective to terms being used, with two occurrences of the label INSTRUMENT.

‘Cloud’ also showed major label variation (10 out of 18 classified in this paper were applied), as well as ‘wind’ (9 labels), indicating higher relevance of those terms to the field of aeronautical meteorology. As a matter of fact, the World Meteorological Organization (WMO, 2003) states that “the primary forecast elements are the surface wind, visibility, weather and cloud.” (p. 13). In this line, the International Civil Aviation Organization (ICAO, 2018) states important weather information related to aviation as “information on visibility, runway visual range, present weather and cloud amount, cloud type and height of cloud base” (p. 4-6). This is convergent to the previously discussed perspective of weather influence to runway conditions, as a direct product of weather phenomena (Cf. ICAO, 2018; WMO, 2003).

In addition to these findings, some interesting cases have to be highlighted and discussed, as shown in the reference corpus. Regarding ‘conditions’, it is interesting to note that this term was used a significant number of times in the text with the meaning of possibility or objective condition of air traffic elements (surface conditions; and conditions, such as workload, traffic volume, the quality/limitations of the radar system) not related to weather phenomena. In this paper, however, occurrences were selected only when ‘conditions’ referred to general standards of atmospheric phenomena, not conditions as status of equipment, for example. The polysemy shown here, however, stresses the possible nuance of terms, only clarified when considering the contextual reference to collocates. As discussed at the beginning of this paper, defining the whole scope of pattern of a term is always a very sensitive task. Although runway conditions may be indeed related to meteorological phenomena it does not constitute a weather situation in itself since it is not an ongoing process, but the product or result of a previous meteorological condition.

Regarding ‘lightning’, there were some occurrences of ‘blue lightning event’, particularly in Order JO 7110.65W (UNITED STATES, 2015), but with a different meaning when compared to primary concept of ‘lightning’ within the aeronautical context. As a matter of fact, ‘blue lightning events’ refers to “reports of possible human trafficking”. As publicized in the website of the U.S. Department of Transportation, the Department to which FAA belongs, this expression is explained as:

The Blue Lightning Initiative (BLI), led by the Department of Transportation, the Department of Homeland Security, and U.S. Customs and Border Protection, is an element of the DHS Blue Campaign. The BLI trains aviation industry personnel to identify potential traffickers and human trafficking victims, and to report their suspicions to federal law enforcement. To date, more than 100,000 personnel in the aviation industry have been trained through the BLI, and actionable tips continue to be reported to law enforcement. (UNITED STATES, 2020).

As lightnings may pose major threats to air traffic operations, airports use human observation as well as specific detection equipment to support weather phenomena analysis. Annex 3 (ICAO, 2018) informs that

At aerodromes with human observers, lightning detection equipment may supplement human observations. For aerodromes with automatic observing systems, guidance on the use of lightning detection equipment intended for thunderstorm reporting is given in the Manual on Automatic Meteorological Observing Systems at Aerodromes (Doc 9837). (ICAO, 2018, p. APP 3-13)

The use of ‘formation’ is quite often related to aircraft arrangement (join-up and breakaway) during performed flights, generally conducted in VFR weather unless otherwise approved, as indicated in Order JO 7110.65W (UNITED STATES, 2015). The few cases where formation is used in the context of weather phenomena is when referring to ‘formation/cell operations’ and ‘formation/cell envelope’.

A related term is ‘build-up’, which is shown in broader aviation literature of WMO and ICAO as generally referring to some accumulation of substances as water, snow or ice (‘build-up of ice’, and ‘ice build-up’, ‘water build-up’); or accumulation of some sort of reaction, such as ‘build-up of static electricity’. In other situations not related to weather phenomena, ‘build-up’ is also used in the sense of evolution of services or operations as in ‘build-up of services’ and ‘volcano build-up to an eruption’. This latter sense is more related to a general sense of “an increase, especially one that is gradual” or “an increase in the amount of something over a period of time”, as indicated in the Cambridge Dictionary.

The term ‘cloud’ is the one showing most interesting lexical semantic associations. ‘Cloud’ is the general term comprising specific types of cloud, such as CB (Cumulonimbus) or TCU (Towering Cumulus)

clouds, which is often used independently as well (as CB or TCU only, without the word ‘cloud’). Occurrences of CB in the corpora mostly refer to meteorological codes to be used in forms and systems; and there are occurrences of ‘cumulonimbus CB’, and its variation ‘cumulonimbus CB’, only found in ICA 105-12 (BRAZIL, 2014).

It is important to highlight that the analysis carried out in this paper did not intend to find overall patterns for these terms but phraseological patterns in the ATC language prescribed in the compiled reference corpus, which addresses ATC and weather situations.

This terminological perspective contributes to deepen understanding on how terms work and confirm the perspective that they are very inter-related to adjectival patterns, which require more emphasis on adjective order for example, as well as specific adjectives to be collocated with related nouns, as more broadly discussed in the next section.

5 Weather events in air traffic control communication in learner corpus: discussion and implications for Aeronautical English courses

When it comes to the learner corpus, it is important to emphasize that language patterns may vary a little due to the fact it is a controlled learning environment. For example, related terms are much higher in this learner corpus regarding more common weather phenomena such as rain (17), wind (6) and lightning (10), and how they are associated to other phenomena or situations such as ‘runway’, ‘fog’, ‘gust’, ‘hailstones’, ‘lightning’, ‘CB’, ‘tailwind’, ‘thunderstorm’, ‘turbulence’, ‘visibility’, ‘wind’, ‘wind shear’, ‘thunderstorm’ and ‘instrument conditions’, in the case of ‘rain’; ‘rough chop’, ‘position’, ‘rain’, ‘temperature’ and ‘visibility’, in the case of ‘wind’; and ‘rain’, ‘thunderstorm’, ‘turbulence’, ‘hailstones’, ‘electrical failure’, ‘CB’, ‘flashflood’, ‘engine’, ‘visibility’ and ‘runway lights’, in the case of ‘lightning’.

Overall, adjectives played an important role in the usage of expressions containing these terms in the learner corpus. For example, ‘heavy’ was the most common collocate with terms analyzed, especially with ‘rain’. Among those, some adjective occurrences reflect linguistic calque, as in the case of ‘strong’ used instead of ‘heavy’: ‘strong rain’ in place of ‘heavy rain’. However, occurrences such as ‘weak rain’ are not

contained in the learner corpus. In that sense, most of those adjective uses are intensifiers, with other occurrences with ‘dense’, ‘intense’, ‘light’, ‘moderate’ and ‘severe’.

As the learner corpus is also representative of the aeronautical language in use, it also contains more verbs, due to the intent to comprise more situated communication, with higher reference to location as well. In our study, there is a varied range of verbs which were used with ‘turbulence’ and ‘lightning’, a pattern which was not specifically explored in the semantic labels in this paper but is relevant to be mentioned. In the case of ‘turbulence’, verbs such as ‘passing through’, ‘flew through’, ‘went through’, ‘passed through’, ‘suffering’, ‘facing’ and ‘experiencing’ were used in many instances and also indicate some level of interference from Portuguese. For ‘lightning’, verbal constructions were mostly based on verbs ‘strike’ and ‘hit’, in both active and passive voices, with constructions such as [VERB IN PASSIVE VOICE + DIRECT OBJECT]; [VERB IN PASSIVE VOICE + INDIRECT OBJECT]; [VERB IN ACTIVE VOICE + DIRECT OBJECT]; AND [VERB IN ACTIVE VOICE + INDIRECT OBJECT]. Some examples are ‘striked⁸ by a ~’; ‘a strong ~ struck the engine’; ‘a strong ~ struck us’; ‘a ~ has struck us’; ‘a ~ has struck my left engine’; ‘~ stroke our landing equipment’; ‘hit by a ~’; ‘a ~ hit our left wing’; ‘a ~ hit us’; ‘we were hit/struck by a ~’; and ‘I had my right wing hitted for a ~ strike’. The consequences are sometimes reported and usually related to some kind of technical failure as in “We was hit for a lightning strike and had an electric system failure”.

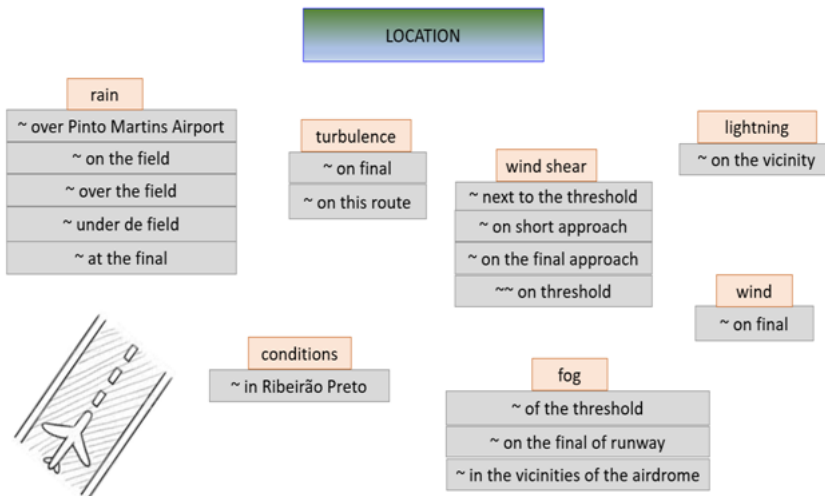
Concerning the term ‘conditions’, likewise in the reference corpus, there are occurrences which are directly related to meteorological phenomena and some others which comprise a broader scope regarding runway conditions. There is one special example which is in the “crossroads” of this differentiation: instrument meteorological conditions (IMC) and instrument flight rules (IFR) conditions, both found in the learner corpus. While IMC literally mentions the meteorological factor, IFR focuses on the use of instrument rules, applied in cases when the airport has such poor weather conditions that it is necessary to rely more

⁸ As mentioned in the methodology, we did not correct students’ grammar errors. In these examples, the incorrect forms ‘*striked*’ and ‘*stroke*’ were used by students instead of the correct form ‘*struck*’. We will not refer to the grammatical correct form of other examples.

heavily on flight instruments to be able to land the aircraft. This example is particularly interesting to emphasize how meteorological phenomena affect many air traffic situations as a whole, as described in WMO (2003) when mentioning weather hazards.

Regarding the semantic label ‘location’, it was also found in a high number in the learner corpus, as a clear indication of fine-grained weather report during all phases of flight, as it happens in ‘rain on final (approach)’, ‘rain on over the field’, ‘rain over the field’, ‘rain over Congonhas’, ‘over the Guamá river’, ‘rain under the field’, ‘rain in the threshold on the runway’, ‘rain is approaching the aerodrome’, ‘over the airdrome, and ‘over the runway’. Some of these occurrences for each term are illustrated in the following figure.

FIGURE 3 – Occurrences of the semantic label LOCATION



Source: Authors' own elaboration.

A summary of lexical semantic occurrences and labels for each key term analyzed in this paper, and the corresponding semantic density, is shown in the table 8.

TABLE 8 – Profile of semantic labels for each term in the learner corpus

Term	Total of occurrences ⁹	Total of labels	Semantic density
rain	29	5	17%
wind	22	10	45%
wind shear	14	5	36%
turbulence	25	8	32%
wake turbulence	1	1	100%
conditions	13	7	54%
lightning	17	5	29%
formation	11	8	73%
cloud	9	6	67%
fog	18	6	33%
thunderstorm	11	6	55%

Source: Authors' own elaboration.

As indicated in the table, terms ‘rain’, ‘lightning’, ‘turbulence’ and ‘fog’ have the lowest semantic density, with 17%, 29%, 32% and 33%, respectively; and ‘formation’ and ‘cloud’ have the highest diversification of semantic labels, accounting for 73% and 67% respectively.¹⁰

When it comes to didactic applications of aeronautical meteorological terms, there are some interesting aspects to note. Some uncountable nouns as ‘rain’ are used as countable nouns, with the inclusion of indefinite article, as in “We are undergoing a formation and facing a heavy rain”. In the same way, an indefinite article is also used in “We received in the short end a tailwind with 15 knots” and “We have a electrical failure due to a lightning, strike the airplane”. Sometimes the article may be used or omitted, as in “We are facing a thunderstorm on FL180.” and “There is Thunderstorm over Porto Velho Airdrome, pay attention.”.

In aeronautical communication, it is paramount to provide sensitive information on weather (ICAO, 2010). The importance of

⁹ Wake turbulence’ was not taken into account because there was only one occurrence, then semantic density was 100%.

¹⁰ ‘Wake turbulence’ was not taken into account because there was only one occurrence, then semantic density was 100%.

warning pilots regarding these meteorological conditions is present in some excerpts in the corpus, as in the listed occurrences:

Attention, the runway 13 is slippery.

(2) Fortaleza is below minimum VFR due to bad weather, heavy rain. Caution, for your information the aircraft has just landed before said he went through a chop on final and other one reported a windshear on short final.

(3) Fortaleza is operating IFR conditions below minima due to heavy rain, the last aircraft that landed, reported thunderstorm with lightning strike, when he was 3nm out.

(4) Rain and low visibility on final, alternate to Manaus airport.

In some examples, other consequences or damages are also informed as in:

we are facing severe turbulence and we are losing oxygen.

(2) we are in severe turbulence and we have lost the weather radar.

(3) Right winglet was broken due to severe turbulence/ has some damage, probably caused by the turbulence /turbulence and one part of my cargo broke.

(4) We got severe turbulence, shaking too much.

Another very important aspect to describe the weather conditions is gradation (from very bad to good), as in “Waiting more than 15 minutes for a better weather condition”, “weather conditions become better to runway 24, few clouds / standby” and “keep hold at this position waiting for weather conditions to improve”. The communication regarding the criticality level of weather leads to requests by the controllers, such as “descend”, “divert”, “immediate descent” and “descend immediately” or required actions such as “avoid turbulence”. Sometimes modal verbs (must / need / will) are also used for that, as in “turbulence. I need descend now”, “turbulence I need divert to my alternative airport” “turbulence. We must land on the nearest AD” and “turbulence. We will need a firefighter, because we...”

When taking into consideration language patterns of the learner corpus, it is important to list all relevant occurrences in order to foresee possible mistakes and try to find regularities to assess those mistakes properly (RAYSON, 2008). Particularly in the learner corpus there are some other occurrences/mistakes which are relevant for a learning environment but which is not a general language pattern in

standard communication (RÖMER, 2004; PEIXOTO, 2020). Verbs and prepositions seem to add to this, especially in terms of crosslinguistic interference/variation (linguistic calque).

If we compare the semantic labels occurring in the reference corpus and in the learner corpus, it is possible to notice there are some peculiarities regarding language patterns (Table 9).

TABLE 9 – Semantic labels in the reference corpus and in the learner corpus

#	Semantic Label	Reference corpus	Learner corpus
01	CHARACTERISTIC	12	1
02	CHARACTERISTIC / INTENSITY	10	16
03	DIMENSION	6	2
04	DURATION	1	2
05	EPISODE	3	4
06	EPISODE / INTENSITY	-	3
07	FORECAST	12	10
08	FORM	1	-
09	INFORMATION FACTOR	2	2
10	INSTRUMENT	7	2
11	INTENSITY	1	2
12	LAYOUT	23	10
13	LOCATION	-	20
14	MANAGEMENT	4	-
15	MOVEMENT	1	-
16	PARAMETER	8	2
17	PHENOMENON	-	4
18	REFERENCE	9	11
19	RELATED TERM	82	59
20	TYPE	21	15
21	TYPE / DIMENSION	-	1
22	TYPE / INTENSITY	-	1
23	UNIT OF MEASUREMENT	-	3
24	VARIATION	2	-

Source: Authors' own elaboration.

In the learner corpus, there was more variation of semantic labels, including EPISODE / INTENSITY, LOCATION, PHENOMENON, TYPE / DIMENSION, TYPE / INTENSITY and UNITS OF MEASUREMENT. This can be explained by the nature of reported communication, giving specific details on where and how weather phenomena are taking place. This finding is mostly suggested, on the one hand, by the higher occurrence of LOCATION labels, in a total of 20 occurrences regarding all terms in the learner corpus; and, on the other hand, by the fact the semantic label MANAGEMENT does not appear in the learner corpus, along with the absence of semantic labels FORM and VARIATION.

6 Final Remarks

Terminological patterns discussed in this paper show how meaning is dependent on context, and how lexical semantic analysis of terms may contribute to reveal nuances of language used in a specialized language. Likewise, this approach also contributes to deepen understanding of language used by students, especially regarding the descriptor vocabulary, prescribed in ICAO rating scale.

However, it is important to stress that analyses carried out in the reference corpus as compared to the learner corpus are illustrative, since occurrences in the learner corpus are controlled and depend on other variables beyond proportional occurrences in natural language expression. Findings suggest learner corpus language focuses on occurrences which are found to be related to more common daily situations, especially within the Brazilian context; and, based on that, semantic density in both corpora is not expected to be the same.

Therefore, results show that the courses have been efficient in teaching and practicing the use of the main meteorological terms related to aeronautical English and that, despite some mistakes students make, evidence indicates that they are able to report weather conditions to pilots and to understand pilots' requests in a proficient level concerning vocabulary. As we've mentioned before, we believe in a more integrated analysis of language production by students, considering the context and the blocks of unit instead of looking at isolated words. In this sense, CL is an efficient tool for analyzing the production of groups of students.

Concerning implications for teaching, there are many analyses that can be conducted by a teacher using the resources of CL. The software used in this paper is free and easy to use with little training – tutorials are widely available. For existing courses, which is the case here, by looking at the concordance lines is possible to compare students' use of the terms, their collocates, the context of use and adjust instruction if necessary. It is possible to monitor a student's development and address him/her individually. It is also possible to apply a data-driven approach and, by showing concordance lines to students, raise their awareness in relation to misuses of a term or the most frequent collocations of it, contrast its use in the learner corpus and the reference corpus, among others. The results presented here can also help researchers and material designers collect authentic descriptions of language usage in a learning environment which, in their turn, may improve teaching and reference materials. This is especially important in the case of aeronautical English, since there are not many courses or material available in the market that deal with specific needs of Brazilian air traffic controllers.

As for implications regarding language testing, we hope this kind of analysis helps teachers benchmark their students' performance in relation to what is expected to NP4 according to the ICAO rating scale. Results also advocate in favor of a more integrated scale and could be used as an argument for ICAO revision of its 16-year-old rating scale. A follow-up suggestion for future research would be to analyze the results of the same students who took the three courses from where the subcorpora were compiled at EPLIS, to check their performance in weather-related tasks and if they achieved PL 4 or above in the descriptor vocabulary, but this is beyond the scope of this paper.

Declaration of contribution

Rafaela Rigaud Peixoto wrote the theoretical foundation section on phraseological patterns and lexical semantic terminological approach, and contributed to the introduction section on aeronautical English. Regarding the methodological planning of the paper, she developed the methodology design, compiled the reference corpus, and articulated the methodological procedures of phase 1 and phase 2. Rafaela performed lexical semantic analysis of weather events in air traffic control phraseology standards, and of weather events in air traffic control communication in learner corpus,

regarding phraseological structures and semantic labels of combinatorics of the 11 selected terms, by using *AntConc* concordancing software. She wrote the abstract in Portuguese and in English. Patrícia Tosqui-Lucks wrote the introductory concepts of aviation and aeronautical English; phraseology and plain English; and ICEA responsibilities concerning teaching and assessment of Brazilian ATCOs. As for the theoretical foundations, she wrote the discussion about learner corpora and ICAO proficiency requirements, including the rating scale descriptors for vocabulary assessment. As for the methodology, Patrícia inserted the data of the learner corpus she compiled into the *Antconc* software and contributed to the analysis of language structure of the 11 selected lexical items as produced by students in classes of air traffic communication for Area Control Centers (ACC), Approach Control Centers (APP) and Towers (TWR).

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