Chapter 1

INTRODUCTION

The only sound on land 3.5 billion years ago was that of wind. The absence of oxygen in the ancient atmosphere, and high levels of harmful ultraviolet light confined life to the water. Bubbles were vitally involved in expanding the abundant life from ocean onto the land. For eons, mats of cyanobacteria (nitrogen-fixing blue-green algae) released tiny bubbles of oxygen as a byproduct of photosynthesis. Eventually, the excess of oxygen in the ocean caused its escape from the water, gradually forming a shield of ozone and changing the composition of the atmosphere . . . . Life could conquer land.

The marine biota is the major source of the persistent background bubble population in the ocean. The second major source, producing transient bubble populations, is purely physical. The air-sea interface is not a simple continuous surface. As the wind blows and transfers more and more energy into the water waves, breaking events occur. Air is entrapped mechanically by breaking waves to form bubbles. The fate of individual bubbles and bubbles in an ensemble – bubble clouds (plumes) – depends on many factors, including

wind velocity, the salinity and temperature of the surrounding water, the concentration of the dissolved atmospheric gases (N_2 and O_2), and the nature and concentration of the surfactants in and on the water surface (Monahan et al., 1995).

It is well recognized that bubbles and bubble clouds are the progenitor of many important processes. Directly, they influence the air-sea gas transfer and sound speed in the ocean. Indirectly, through their bursting, they are involved in all sea spray processes.

The devoted work of many scientists have shaped the contemporary knowledge on bubbles and their role, yet, many questions wait to be answered. This study offers another piece of the bubble puzzle to be scrutinized and, eventually, added to the whole.

The thesis is divided into eight chapters. Chapter 2 gives an abbreviated account of the broad knowledge on bubbles and bubble clouds as physical objects. After definitions (§2.1), the physics relevant to bubble formation is discussed (§2.2). The basics of bubble dynamics are highlighted in §2.3. Bubble acoustics and bubble optics are described briefly in §§2.4 and 2.5 respectively. The effects of including the influence of temperature in the basic equations are discussed in §2.6. As bubble behavior is heavily affected by any surfactants present in the system, the most important traits of surfactants and how they act are summarized in §2.7. Chapter 3 considers bubbles and bubble clouds as oceanographic objects. After justification of further bubble studies (§3.1), sources of bubbles in the ocean, in particular, the process of wave breaking are explored (§3.2). The oceanic processes involving bubbles and the governing equations are reviewed in §3.3. After defining which are

the most important characteristics to be measured (§3.4), the critical measurements (§3.5) and the main results of previous bubble studies are summarized (§3.6). The most representative investigations of bubble clouds in field and laboratory are given in §3.7. Chapter 4 briefly explains the principles of the different methods used in bubbles and bubble clouds studies (§§4.1 and 4.2), compares their respective performances and justifies the choice of the use of image technique as the basic method of investigation for this study (§4.3). Sizing discrepancies due to technical problems or more complex reasons is considered in §4.4. Chapters 2 - 4 provide the basis for the thesis goal formulation in Chapter 5. The scientific objectives and expected results are highlighted in §5.1, and the experiments necessary for obtaining those goals follow in §5.2. The core of the present study is in the next two chapters, which contain the experimental results. Chapter 6 describes in detail the experiments on bubble cloud characteristics and Chapter 7 concentrates on the influence of salinity. Both chapters follow one scheme of presentation: First, the equipment employed and the experimental conditions are described. Then, the procedures for data processing are elucidated. Finally, the results and discussions of their implications are given. The conclusions on this work are summarized in Chapter 8.