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# This Week's Citation Classic®

**Blanchard D C.** The electrification of the atmosphere by particles from bubbles in the sea. *Prog. Oceanogr.* 1:71-202, 1963.
[Woods Hole Oceanographic Institution, MA]

Jet and film drops from bursting bubbles produce most of the aerosol rising from the sea. A positive charge on the jet drops, resulting from a stripping of electrical double layers, produces a current from the world ocean to the atmosphere of about 160 amperes. [The *SCI*® indicates that this paper has been cited in over 140 publications, making it the most-cited work in this journal.]

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The work that became my *Citation Classic* began with serendipity about 10 years before publication. One day in the early 1950s, Charles Keith, Alfred Woodcock, and I, then at the Woods Hole Oceanographic Institution, were watching air bubbles burst at the surface of a container of seawater and produce a haze of droplets. We were interested in how bubbles, produced in the sea primarily by breaking waves, generated the atmospheric sea-salt aerosol. High-speed photography had revealed that a water jet rose rapidly from a collapsing bubble to produce several airborne drops.

Out of idle curiosity, one of us took a comb, ran it through his hair to electrify it, and held it near the bursting bubbles. To our great surprise, all the droplets produced by the bubbles moved rapidly upward to the comb! Clearly, they were highly electrified. I was very excited by this finding, but a day or so later realized that the drops were being charged by electrostatic induction in the strong electric field of the comb. I wondered if jet drops produced on the open sea in the absence of a strong induction field also carried a charge. Experiments showed that they would and that the charge was positive. I published two papers on this, went to MIT for doctoral studies, then returned to Woods Hole to do my PhD thesis on a detailed study of the problem.

Along with jet-drop charge measurements, I obtained data on the influence of bubble size on the production of film drops, the tiny droplets generated by the collapse of the thin film of water comprising the dome of a bubble resting at an air-water interface. All this, as well as estimates of the percentage of the sea covered with whitecaps as a function of wind speed and a review of papers on the generation of an aerosol at the surface of the sea, was poured into my doctoral thesis. Two years later, to my great relief, the entire thesis was published as the paper being cited here.

I think the frequent citation of this paper is due less to my discovery of a flux of positive charge from sea to air (my main interest in the research) and more to the detailed studies of jet and film drops. I coined the names for these two classes of drops and used them for the first time in the paper. Timing also was important. I was fortunate to be in on the start of a research area that has grown rapidly in the past 20 years. The work with bubbles, jet drops, and film drops continues on several fronts.[1,2] This is due largely to the widespread interest today in the enrichment of heavy metals and organic materials in the marine aerosol[3] and in satellite remote sensing of the sea.

1. **Cipriano R J, Monahan E C, Bowyer P A & Woolf D K.** Marine condensation nucleus generation inferred from whitecap simulation tank results. *J. Geophys. Res.* (In press.)
2. **Monahan E C & Mac Niocaill G, eds.** *Oceanic whitecaps and their role in air-sea exchange processes.* Dordrecht, The Netherlands: Reidel, 1986. 294 p.
3. **Weisel C P, Duce R A, Fasching J L & Heaton R W.** Estimates of the transport of trace metals from the ocean to the atmosphere. *J. Geophys. Res.—Atmos.* 89:11,607-18, 1984.

 

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