# Christian Junge
# 2 July 1912 – 18 June 1996

*Christian Junge, pioneer of atmospheric aerosol research and air chemistry.*[1]

## Education and Second World War

Born in Elmshorn, Germany on 2 July 1912, Junge was influenced by growing up in post WWI Germany. After his *Abitur* he wanted to study chemistry, but he was warned by seeing unemployed men on the streets wearing posters "*Chemiker sucht Arbeit*"[2]. He was feeling the zeitgeist and the increasing interest in flying and air traffic and wanted to participate in this. He decided to study meteorology, an important discipline for flying, at the University of Graz (Austria). He selected Graz initially because meteorologist Alfred Wegener there *hatte die Lehrkanzel für Meteorologie und Geophysik inne*. Wegener's understanding of meteorology was from the perspective of atmospheric physics. Unfortunately, Wegener was lost in 1930 to the ice of Greenland on his last expedition, so Junge lost the chance to study with him. Junge then pursued meteorology in Hamburg and Frankfurt (1931-35). He finished his education with a PhD while working on atmospheric condensation nuclei (Junge, 1935).

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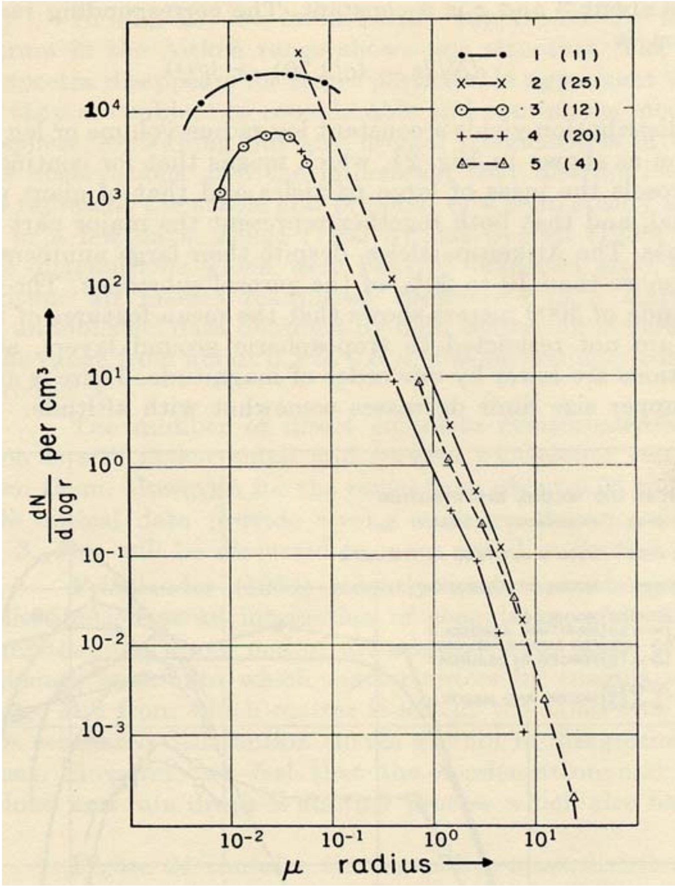
[1] This article will discuss only Junge's atmospheric aerosol merits. He also had superior qualities in atmospheric trace gases.

[2] "Chemist looking for work"

He spent two more years in Frankfurt as university assistant working on condensation nuclei and later joined the German Weather Service (*Reichswetterdienst)* at the Office for Instruments in Hamburg.

With the onset of WWII, Junge became involved almost automatically with the military connection of the German Weather Service to the *Luftwaffe*. His first assignment in WWII was propaganda. Junge was ordered to launch propaganda pamphlets using weather balloons in eastern France so they would fly with the winds across the front line into French-ruled territory. But easterly winds are rather rare in Western Europe and the success of this activity was quite limited. Much of his vivid personal diary of that time resembles pictures of the great 1958 English WWII movie *Me and The Colonel*[3]. Quite impressive is Junge's "confession" of how he deposited unused propaganda material in the *Basilique du Sacré Coeur* in Paris. Junge spent the entire war as weather forecaster on duty in many parts of the war theatre: France, North Africa (Derna, Libya), Crete, and Italy. The war experience shaped his view of meteorology and the atmosphere. Junge carried the full burden of the war, serving as prisoner of war for two years. He became severely ill in Yugoslavia on the return trip. Later, he again joined the *Deutscher Wetterdienst* in Hamburg.




*Atmospheric aerosol size distributions.*
*The dashed line fills the gap*
*where no data existed. (Junge 1953, 1955)*

His professional position after returning from war was that of an experienced weather forecaster and a trained atmospheric physicist with an interest in chemistry. This laid the ground for his scientific career. Junge loved research much more than forecasting, so he returned to Frankfurt for habilitation and was awarded *Privatdozent* (teaching permit for universities) in 1953. These years resulted in remarkable understanding of atmospheric aerosols (Junge, 1952b). Publications at that time (especially from German authors) were "rare". In contrast to today, it was not the sheer number of publications that was important, but the scientific impact of the few publications.

Junge's significance for atmospheric aerosol research rests on three subjects: aerosol size distribution, aerosol chemistry, and the stratospheric aerosol layer.

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3 with Danny Kaye and Curt Jürgens

The understanding of atmospheric aerosol at that time can be compared to a “zoo” of independent particle populations, unconnected and different in particle size, and all labeled differently: Aitken particles, small ions, small medium ions, large ions, Langevin ions, ultra large ions, haze particles (Israël et al, 1932). This was a consistent picture because particle physics at that time offered a similar zoo.

Junge’s training as a meteorologist, especially in the war, meant he was often forced to develop synoptic charts from sparse data. This experience encouraged him to draw a line through all the aerosol concentration points obtained so far. He wrote, “For simplicity, the line spectra of the Aitken particles were converted to continuous distributions” (Junge, 1952b). This way, the first continuous aerosol size distribution was created. Junge used the equation:

$$\frac{\mathrm{d}N}{\mathrm{d}\log r} = cr^{-3}$$ for particles greater than 0.1 µm in radius.

Its simplicity was so convincing that colleagues raised the equation to the rank of a “law”. Even today, if you google for “Junge-law aerosol” you get 6470 hits (9 August 2009). Most probably that “law thinking” was initiated by a remark of Siedentopf to an oral presentation of Junge at that time, “A $r^{-3}$ law of radii distribution is not present in atmospheric dust only, but also in interstellar material.”

That straightforward model of the size distribution dominated scientific view for decades. I remember well a discussion with Ken Whitby in Minneapolis in 1971, when he questioned Junge’s straight line because Junge had simply drawn a line though the gap that had no data. Later Whitby (1973) introduced the concept of the multimodal nature of atmospheric aerosol and Jaenicke et al (1976) added the mathematical formalism used today.

Junge’s scientific future appeared dim in Germany during the 1950s. Therefore, he accepted an invitation by Dr. Helmut Landsberg, then Director of the Geophysics Directorate, USAF Cambridge Research Center, Bedford, Massachusetts and moved to the US.

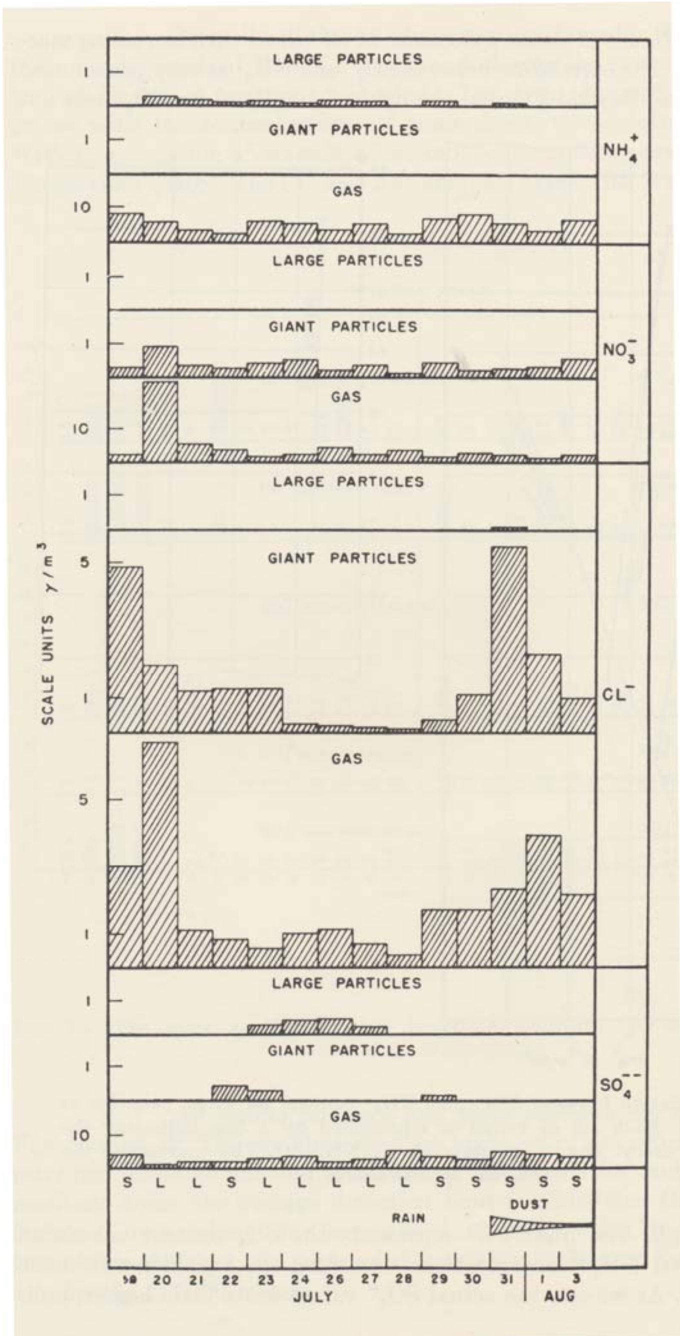
## The US Career and the Chemistry of Atmospheric Aerosols

Junge’s interest in the chemistry of atmospheric aerosols started with his research into the growth behavior of Aitken particles (Junge, 1952a). The growth of particles in a humid atmosphere is of great importance for cloud physics. The growth factor for particles found by Junge is still widely referenced today. At that time, the concept of the mixed nature of atmospheric aerosol particles evolved. Well-mixed particles seemingly made it easy to study the chemical composition because the meteorology seemed to be of a minor influence. Investigations could be undertaken without carefully following the atmospheric history of a specific air parcel. Chemical studies of the atmospheric aerosol were separated from meteorology! Today that connection is re-emerging.

In the US, Junge’s interest shifted again to the chemistry of atmospheric aerosols. What was known at that time? Atmospheric aerosol particles serve as cloud condensation nuclei. Certain chemicals should foster this process. Electron microscope diffraction diagrams of individual particles showed ammonium sulfate being present (Jacobi et al, 1952). Those and other results showed the approximate character of aerosol particles. Quantitative data were completely absent. 50 miles outside Boston (Round Hill), Junge made measurements with impactors and micro techniques, primarily with color reactions (Junge, 1954). Impactors permitted him to divide the aerosol into fractions, large nuclei 0.08 to 0.8 µm and giant nuclei 0.8 to 8 µm in radius. Those measurements were later complemented by measurements in Florida. The pronounced chemical difference between particles larger and smaller than 0.8 µm radius was established. It may have later influenced Whitby in developing his idea about the multimodal structure (and source difference) of atmospheric aerosol.

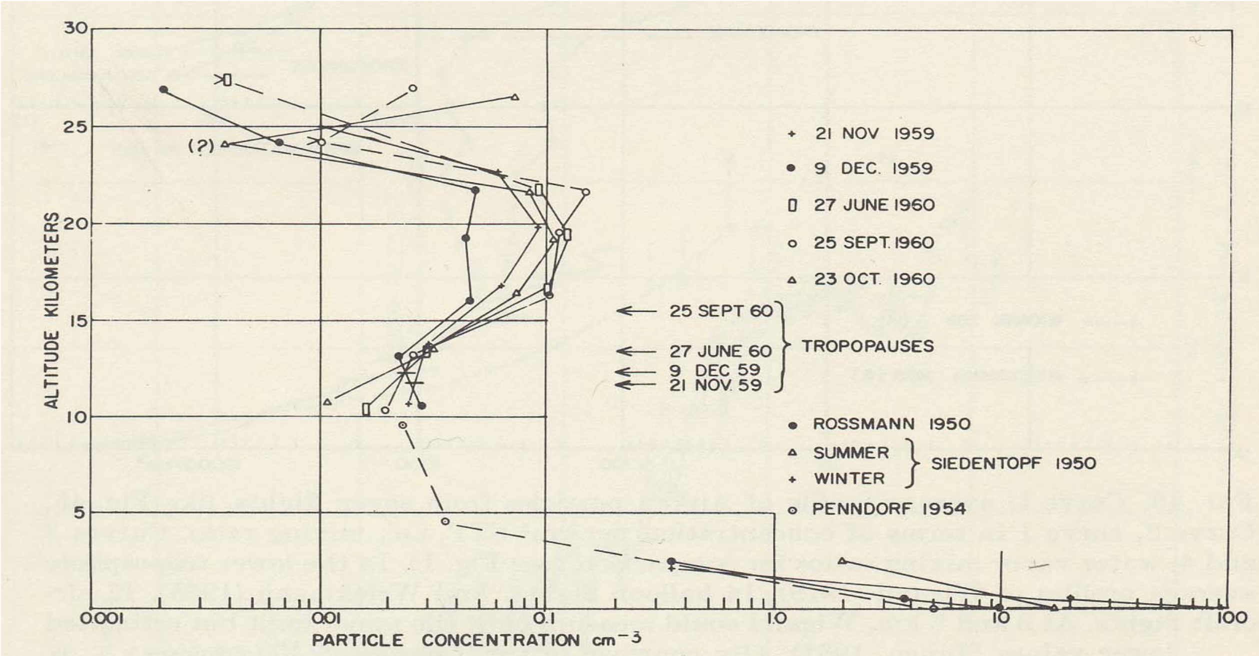
It is interesting to note a dust event in the Florida data. As a meteorologist trained in the desert, Junge easily identified Saharan dust. Despite that, other scientists (Delany et al, 1967) later selected the “pristine” air of Barbados to study micrometeorites because they could not imagine Saharan dust crossing the Atlantic Ocean. The benefit today from this ill-fated initiative is the impressive time series of Saharan dust transported to Barbados (Prospero, 1999).[4]

4 October 1957 was a turning point in American research strategies. The USSR successfully launched the first artificial satellite, much earlier than expected. The efforts and funding of US research installations were diverted to space science. Public pressure was enormous. What was then the role of an atmospheric chemist in a US Air Force research establishment?




*The chemical composition of aerosol particles in 1954 in Homestead, Florida ($\gamma/m^3 = \mu g/m^3$). (Junge, 1956)*

4 In connection with the chemistry of atmospheric aerosols it is interesting to note that Junge was the first to establish a precipitation chemistry network in the US (Junge et al, 1956), following the Scandinavian original (Egnér et al, 1955) of Europe.




*Five stratospheric profiles of large particles*

*obtained over Sioux Falls, South Dakota (Chagnon et al, 1961).*

Junge proposed studying micrometeorites in the stratosphere as a possible threat to satellites. The stratosphere had previously been of scientific interest because of nuclear test explosions and the possibility of tracing stratospheric transport. In addition, Penndorf (1954) for the troposphere and Bigg (1956) had concluded from twilight measurements that a vertical distribution of dust existed, resulting in layers. Proof of this was, however, missing.

Junge was given plentiful resources for conducting that research. He launched balloons from Sioux Falls and Hyderabad, India. Additionally impactor probes were secretly[5] carried on U2 reconnaissance planes, at that time unknown to the public. The result surpassed all expectations. The stratospheric aerosol layer (see South Dakota figure) was established (Junge et al, 1961). This aerosol layer continues to play a key role in today's ozone hole and climate research. However, with his heart in chemistry[6], Junge also looked into the chemical composition of the particles collected (Junge et al, 1961). The research success of this program caused an unexpected end to the program when he found an abundance of $SO_4^=$, a "sulfate layer". This was a clear indication of terrestrial origin of the layer rather than origin from space. That layer continues to be called the Junge or sulfate layer.

## German Career

Junge's research no longer had connections to space. His post at the Air Force Cambridge Research Center was terminated. He returned to Germany in 1962 and became Professor for Meteorology at the University of Mainz. In 1968, he was appointed director of the Max-Planck-Institute for Chemistry and formed the Department of Atmospheric Chemistry. For the Max-Planck-Society, he was their second choice. They aimed first for Nobel Laureate Rudolf Ludwig Mößbauer (Mossbauer Effect) who had refused the offer. But on occasion,

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[5] By secretly, we mean that all U2 flights were government secrets. Even though Junge had become a US citizen, he was not told of the flights because he was from Germany. He was only told that the measurements were made at a specific height, geographical location, and exposure time.

[6] Even if Junge never followed an academic chemistry lecture

second choice is better than first choice. The department became a success story because Junge brought many scientists of different fields together undertaking studies on atmospheric aerosols, trace gases, reaction kinetics, and the "old atmosphere". This work deepened the understanding of the physics and chemistry of the atmosphere, and laid the ground for the successor, Paul Crutzen, and resulted in the Nobel Prize for chemistry for Crutzen, Rowland, and Molina in 1995. In that way, air chemistry became an accepted science in the eyes of the public.

## The Scientist and the Person

Working with Christian Junge was a demanding job and a mind-shaping experience. He was an inspiring teacher, giving complete and consistent views rather than collections of facts. He had developed a coherent view of the atmosphere, sorting out and rating different published ideas. The inexperienced student or newcomer had no sorting to do for themselves. This contrasts with many teachers and textbooks today that offer the reader all the conflicting ideas and observations - then leave the reader alone to draw conclusions. Junge presented his views so that the front and the end fit together, making the picture complete and sound. This way of teaching is only possible if the teacher has profound knowledge, experience, and bright scientific imagination.

That also was the way Junge tackled research. He had visions about subjects that other people had never thought of, even if it was resting in front of their eyes. So he began studying those atmospheric traces that chemists had always seen but considered to be anomalies rather than study objects. Some people certainly don't like this approach. They often study an object to the last comma, but fail to see more important issues.

*Making color reactions on Tenerife, Canary Island 1968.*

Junge was an enthusiastic experimenter. Experimental data always convinced him. So experimental data came first and theories later. In tackling scientific issues, the questions came first and then the instrument needed for measurement. If the instrument or procedure was not at hand, he invented it. This approach is unlike many others who have an instrument and then look for applications, often overstating the capabilities of their instrument. Returning to Germany, Junge spent all the resources the University of Mainz offered as seed money for his new professorship to purchase a Goetz aerosol centrifuge (Goetz et al, 1961). I remember well Junge's deep dissatisfaction when he discovered the very limited radius range of the aerosol centrifuge when used for atmospheric studies. Junge never published a paper using that instrument.

To his colleagues, his forward-looking views were not always appreciated. They stirred up unchallenging lives and content positions.

Junge served the scientific community in many positions: President of the Commission on Atmospheric Chemistry and Global Pollution of the International Association of Meteorology and Atmospheric Physics (IAMAP, 1967-75), President of IAMAP (1975), and President of

Gesellschaft für Aerosolforschung (GAeF, 1977). The science community honored his work with many awards. To name a few: Member of the Leopoldina Academy of Science 1965, Alfred-Wegener-Medal of the *Verband Deutscher Meteorologischer Gesellschaften* 1968, Carl-Gustav-Rossby-Medal of the American Meteorological Society 1973.

The European Aerosol Association created the Junge Award in honor of Christian Junge. The Junge award is intended to recognize outstanding research contributions of an individual who shaped a completely new field of aerosol science and/or technology, as Junge did for atmospheric chemistry. The first recipient in 2000 was Sheldon Friedlander.

In 2002 his birthplace the city of Elmshorn in Northern Germany named a new street after Christian Junge. Thus, his name will also be remembered by the public.

*Christian Junge, shown here with his wife Inge, retired in Überlingen.*

However, any monument also casts a shadow. As for Junge, he offered such a convincing picture of the atmospheric aerosol that researchers of the time became almost blind to other explanations and possibilities or overlooked effects. They simply copied his ideas. As an example, we might suggest biological aerosol. It had no place in Junge's "chemical model" of atmospheric aerosol. It is only today (Jaenicke, 2005) that a few researchers are realizing the important role biological particles may play in forming ice nuclei and cloud condensation nuclei. Pratt et al (2009) suggested that 50% of ice crystal residues are of biological material.

Christian Junge was a very conservative and traditional minded person. Rooted in a wood mill in Elmshorn, Germany, he needed lots of discipline and drive to succeed in an academic career. That control was further strengthened during his duty as an official in the German Weather Service. So, for instance, he always spoke of going to the "*Amt*"[7] rather than to the office when he went to the Max-Planck-Institute. Coming from a physician family in Berlin, his wife Inge supported that traditional understanding. They raised two girls during the difficult years after the war. The family clung together under all circumstances. The adult girls returned with her parents to Germany and still live there.

[7] "*Amt*" in German means any public office

*Hohenpeissenberg, a painting attributed to Christian Junge.*

*Ernst Barlach: The Singing Man; Barlach was a relative of Junge.*

After retirement in Mainz, Junge and his wife moved close to the residence of one of their daughters at Lake Constance. There he followed his leisure pursuit of history (including family genealogy), art, and anthropology. Because one of his relatives was the German expressionist sculptor Ernst Barlack (1870-1938; see example in the figure), Junge was interested in art. In 1991, he wrote an anthropological draft *Die Unersättlichkeit des Menschen; Gedanken zur Evolution seiner Intelligenz*[8], and was very much disappointed that specialists of that time rejected it. As in science, Junge was always enthusiastic about his actual personal interests. Those interests ranged from history to politics.

Junge retired very abruptly from atmospheric science after reaching retirement age, forcing the decision to select his successor, the later Nobel Prize laureate for chemistry, Paul Crutzen. Christian Junge died 18 June 1996 in Überlingen at Lake Constance surrounded by his family. His wife Inge died in 2001 in Überlingen.

[8] The Insatiability of Mankind; Thoughts about the Evolution of His Intellect.

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