Paul J. Crutzen – interactions with friends and colleagues

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Abstract. Paul J. Crutzen was a brilliant scientist and a pioneer in atmospheric sciences. At the same time, he was a kind-hearted, humorous and pleasant person. Paul was deeply empathetic toward the personal lives of his colleagues and students, always making time for those around him – especially his family. This tribute brings together a series of anecdotes shared by friends and five colleagues, offering a more intimate portrait of the man behind the science. Collectively, these reflections reveal aspects of Paul Crutzen that may be overlooked when focusing solely on his extraordinary scientific accomplishments – yet they were integral to his ability to achieve them.

1 Introduction

Paul Crutzen was a brilliant scientist. Having begun his career as a bridge-building engineer, what makes his scientific achievements all the more remarkable is the breadth of topics to which he made significant contributions over the years (Crutzen, 1996; Müller, 2022; Fishman et al., 2023). His interests spanned topics relevant to a majority of the atmosphere, with a particular focus on the mesosphere, stratosphere, and troposphere. Among other things, he first described the NO_x–driven ozone loss cycle in the stratosphere (Crutzen, 1970), he recognised that emissions of NO_x caused by a possible fleet of supersonic planes could have a detrimental effect on stratospheric ozone (Crutzen, 1970; Johnston, 1971; Crutzen, 1972), he investigated how tropospheric nitrogen containing compounds (like N_2O) can enter the stratosphere and cause the formation of stratospheric NO_x (Schütz et al., 1970; Crutzen, 1970; Crutzen and Ehhalt, 1977), he was among the first to develop mechanisms for the chemical formation of ozone in the troposphere (Crutzen, 1973; Chameides and Walker, 1973; Fishman and Crutzen, 1978; Fishman et al., 1979a, b). He further contributed key ideas on how to explain the "ozone hole" (Crutzen and Arnold, 1986); today the focus is on the recovery (or "healing") of the Antarctic ozone layer (e.g., Kuttippurath et al., 2013; Solomon et al., 2016; WMO, 2022). Paul also made fundamental discoveries on the impact of biomass-burning and aerosol particles on the troposphere (e.g., Crutzen et al., 1979; Crutzen and Andreae, 1990; Lelieveld et al., 2001; Ramanathan et al., 2001).

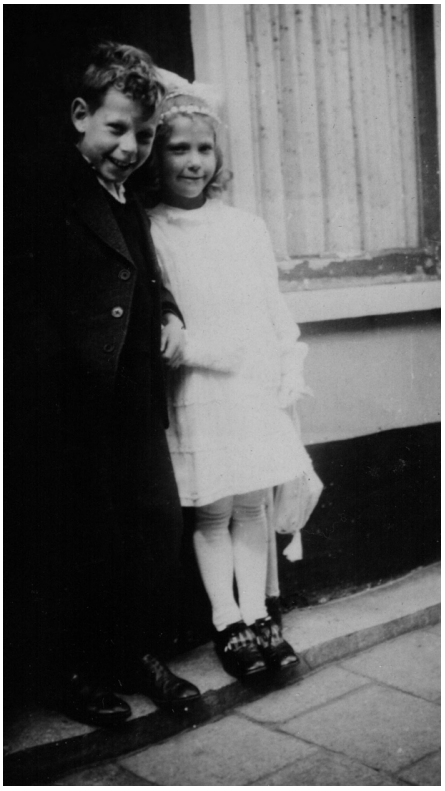

Figure 1. Paul Crutzen as a child together with his younger sister Elisabeth (Lies). (Picture courtesy of Ilona Crutzen.)

Moreover, Paul's work on smoke from fires after a hypothetical nuclear war, inspired new research on a concept now known as "nuclear winter" (e.g., Crutzen and Birks, 1982; Birks and Crutzen, 1983; Turco et al., 1983; Robock, 1984; Robock et al., 2023). By writing an essay (Crutzen, 2006), he also initiated the resumption of the discussion on "geoengineering", a concept today referred to as "climate intervention" (Visioni et al., 2023). Paul coined the term "Anthropocene" (e.g., Crutzen, 2002; Crutzen and Steffen, 2003; Crutzen and Müller, 2019; Benner et al., 2021). And in 2000, he was also one of the founders of the journal "Atmospheric Chemistry and Physics" (Müller et al., 2023; Ervens et al., 2025), which pioneered having a transparent peer review and open access, (Pöschl, 2012; Ervens et al., 2025). Initially, his research focused on understanding the fundamental processes of the Earth's atmospheric system. Over time, however, the driving force behind his scientific work shifted toward understanding the origins of human-induced impacts on the atmosphere and climate – and finding ways to mitigate these effects. (e.g., Crutzen, 1996; Müller, 2022; Fishman et al., 2023; Müller et al., 2023).

Beyond his scientific achievements, Paul played a pivotal role in advancing atmospheric and climate science through his mentoring and education of young researchers. Many outstanding scientists began their careers under his guidance. Several of them are still active today. Many of these scientists later became mentors themselves, guiding a new generation of researchers. As a result, Paul can now be considered to have "scientific grandchildren – and even great-grandchildren".

Paul himself provided an excellent description of his life and of his scientific work in his Nobel lecture (Crutzen, 1996) on the occasion of the 1995 Nobel Prize in Chemistry, which he shared with Mario J. Molina, and F. Sherwood Rowland (Harris, 2020). Further, shorter biographical texts are available (Möllers et al., 2015; Lelieveld, 2021; Moortgat et al., 2021; Rodhe, 2021; Solomon, 2021; Zalasiewicz et al., 2021; Zetzsch, 2021) and also more detailed memoirs (Lax, 2018; Müller, 2022; Müller et al., 2023; Fishman et al., 2023). The idea of the present contribution is not to enhance previous biographical texts, but rather to complement this information with personal accounts of an interaction with Paul by a number of his colleagues and friends. Paul had a profound influence on the scientists he worked with, thanks to his unique blend of scientific curiosity and deep humanity.

2 Paul Crutzen's life

Paul Jozef Crutzen was born in Amsterdam on 3 December 1933. He remained a Dutch citizen all his life. He grew up with his younger sister Elisabeth (Lies) (Figure 1) who lived all her life in Amsterdam. Paul passed away in Mainz on 28 January 2021. On 14 February 1958, in Amsterdam, he married Terttu Soininen. This day is known today as 'Valentines day' but in 1958, Paul and Terttu were not aware of this fact. Terttu and Paul have two daughters, Ilona and Sylvia (Figure 2) and three grandchildren. Paul's life has been described in detail elsewhere (e.g. Lax, 2018; Müller, 2022; Fishman et al., 2023), so a description of his life is not repeated here.

On 1 July 1959 Terttu and Paul moved to Stockholm. Paul initially took a position at the Meteorological Institute of Stockholm to work in computing. However, his potential was quickly recognised, and alongside his duties, he managed to complete his degree in meteorology. He then continued as a doctoral student at the Institute, ultimately earning the Swedish equivalent of a doctorate. In 1973, he completed the "Filosofie doktor", which is roughly equivalent to a habilitation (Müller, 2022). In 1974, together with his family, Paul moved to Boulder, Colorado in the United States; he first took positions at both NOAA (National Oceanic and Atmospheric Administration) and NCAR (National Center for Atmospheric Research). Later, in 1977, he became a director at NCAR. In 1980, he moved back to Europe and accepted the position as a director of the Air Chemistry Department at the Max-Planck-Institute of Chemistry (MPIC) in Mainz as the successor of Christian Junge. Ruprecht Jaenicke went to the University of Mainz at the same time. Ruprecht possesses a movie-clip where Paul explains that he proposed Christian Junge for the Nobel Prize. This shows, how much Paul valued Christian Junge.

Paul was from the Netherlands, so Dutch was his mother language. On the occasion of his visit to Jülich on 15 February 1996 (section 3.6.2) Paul spoke in Dutch to a Dutchman employed at the "Forschungszentrum Jülich" (Martin Böhmermann). Martin Böhmermann could hear clearly from Paul's accent that he was from Amsterdam, and (in Martin's words) not from the richest part of town.

Paul's parents on his mother's side were of mixed German and Polish origin and lived in the Ruhr region in Germany, while his father had relatives in the Netherlands, Germany, and Belgium. Thus, at a young age, Paul inherited a cosmopolitan view of the world. He learned the value of being fluent in several languages, as his own family spoke a mixture of languages and dialects. At school, he learned French, English and German, but later in Sweden, Swedish became the language of the Crutzen

family (Müller, 2022). He also had started learning Finnish – Rolf Müller recalls that Paul translated the legend of a Finnish plot from Sodankylä for him. But (in Paul's own words) he stopped learning Finnish, as this was part of an agreement with his wife. She would stop smoking (which she did very moderately, but which he hated nonetheless) and he would learn Finnish. However he pointed out that once he had learned Finnish, he could not unlearn it whereas Terttu could start smoking again!

3 Anecdotes

Figure 2. Paul Crutzen with his daughter Ilona at the beach. (Picture courtesy of Ilona Crutzen.)

Despite his concentration on science, Paul was a very warm-hearted, friendly and humorous person, who always had time for his family (Fig. 2). He never forgot how important the private life of his colleagues and students is, a fact that was an intrinsic part of any collaboration and interaction with Paul (Müller, 2022; Müller et al., 2023; Fishman et al., 2023). Having set the scene, this contribution offers a collection of stories–both scientific and personal–shared by colleagues and friends who have interacted with Paul.

3.1 Conversations with Lennart Bengtsson in Summer 1995

Paul Crutzen contacted his good friend Lennart Bengtsson in summer 1995. He asked if Lennart could arrange him to be invited to the Nobel ceremonies later that year. Of course Lennart knew things he could not talk about at that time, so he did not say anything. All that Lennart said was, yes, he would work on the issue and he was confident that things could be resolved eventually. Of course, things were resolved and Paul was indeed invited to Stockholm towards the end of 1995 for reasons everybody knows today.

3.2 John Birks remembers

The first time John Birks ever interacted with Paul was when they were on the same flight from Champaign, IL to Washington, DC, so Paul arranged for them to sit together. The flight had an intermediate stop somewhere, and John realised that his bag had only been checked to that airport. So he had to get off the plane, collect the bag and recheck it. When he had not re-boarded and they were closing the door to the plane, Paul convinced the flight attendants to hold the plane for John.

John greatly admired Paul and got to know him and Terttu very well during John's year in Mainz. Paul was part of the reason John moved from the University of Illinois to the University of Colorado when Paul was at NCAR, and he followed him to Mainz for his first sabbatical a year after Paul had moved to Mainz (section 2). John lost touch with Paul after the nuclear winter days, but they joined forces again to work on asteroid impacts around the time John retired from university and started his company.

3.3 John Burrows remembers

3.3.1 First introduction to Paul Crutzen

John Burrows first met Paul Crutzen in early March 1977 at the NATO Winter School in Arabba, in the Dolomites, Italy, when John was a doctoral student at the University of Cambridge (under the supervision of B. A. Thrush). John was studying free radical reactions of importance in the atmosphere. The meeting in 1977 was organised by Professor Karl-Heinz Becker of the Bergische Universität Wuppertal. It brought together many of the leaders of the then rapidly evolving field of atmospheric chemistry – but also involved the younger generation in this field. One of the reviewers of this paper also attended the winter school in Arabba (see Discussion)

Paul gave some impressive lectures. The second half of which were particularly remarkable, as he delivered them, after sustaining a broken leg while skiing down the Marmolada in bad weather. Paul was a gifted communicator and filled the young and older scientists at this school with his enthusiasm about the importance of studying stratospheric and tropospheric ozone. This meeting demonstrated the fun, which this senior scientist found in his research.

3.3.2 Joining Paul's department

While John Burrows was a researcher at the UKAEA (United Kingdom Atomic Energy Authority) and at the University of Oxford, he was offered a position at Paul's new department of Air Chemistry at the Max Planck Institute for Chemistry in Mainz (see section 2), joining in late 1981 to work with his group leaders Geert Moortgat and David Griffiths on kinetics and spectroscopy of key atmospheric constituents. John was attracted by the lively atmosphere of this new department.

In this period Paul was busy investigating the impact of a hypothetical nuclear war on the atmosphere together with John Birks (see section 3.2). Their findings, which they called "twilight at noon" (Crutzen and Birks, 1982), later became known as nuclear winter (Robock et al., 2023). These studies and the controversy at that time led to fascinating coffee time discussions. Paul did an excellent impression of Edward Teller, the father of the H Bomb, who was at least initially sceptical about the concept of nuclear winter. Apparently Teller gave monologues bearing down on his audience without ever looking at any notes!

John is also grateful to Paul and Terttu, who regularly invited him, his future wife and other colleagues to dinner, where the after dinner coffee from Terttu was a special treat. Paul and Terttu were both good at looking after John without him realising it. John Burrows also shared the passion with Paul for sport in general and in particular football[1] (Müller et al., 2023). Paul had played for Ajax Amsterdam youth teams in his youth and, at the age of 50, was still was a good midfield player. He played in the Air Chemistry All-stars football team, which bound all players together. John also enjoyed watching international football games together with Paul and Terttu. Although Paul always had a busy schedule, he found time for such activities.

3.3.3 Paul as a science manager

Paul was a unique person, a powerful advocate for research, full of ideas and always trying to push the envelope of our knowledge. He led by example. In managing people, he developed individual relationships with his scientists. He was able to encourage and inspire, being also a kind, good humoured and warm hearted mentor. He played an important role in John Burrows remaining in research, when John was unsure about his own future.

Paul was also a calculated risk taker. In this respect he should be seen as a "why not" person rather than a "why" person. In general, as well as having his own great ideas about atmospheric chemistry, he would listen to ideas of others about science priorities carefully. He was always interested in hearing about potentially important and doable atmospheric science.

One personal example is as follows. In 1983, he asked John Burrows to move to his new research group called optical measurements of atmospheric constituents, joining Dieter Perner. The focus was to be on remote sensing and in situ measurements of key atmospheric constituents. Over a coffee time discussion, Dieter, Paul and John talked about some potential remote sensing options. They discussed the use of the differential optical absorption spectroscopy (DOAS), which has been developed by Dieter and Ulrich Platt at Forschungszentrum Jülich (e.g., Perner and Platt, 1979). John thought that this idea could be exploited successfully when applied to space borne spectrometer measurements. They both agreed! This led to Paul's and Dieter's support and in 1984 to the first MPI attempt to propose a mission in response to an ESA (European Space Agency)

[1] Football is the game referred to in American English as soccer.

call for ideas to exploit a free flying small satellite for earth observation, released from the space shuttle. This proposal failed but gained ESA's attention. This then led to John leading the development of the proposals called SCIAMACHY (SCanning Imaging Absorption spectrometer for Atmospheric CHartographY) and SCIA-mini, supported by Paul, Dieter and a strong team at the MPI in Mainz, as well an international science team (Burrows et al., 1995).

3.3.4 Paul as a government adviser and science advocate

Paul was someone who researched science of importance to society. In this context, Paul also served science by successfully advising government. Of particular relevance here was his participation in the Federal German Government Enquete Commission entitled "Precautionary measures to protect the Earth's atmosphere" from 1987 to 1991 (Schmidbauer, 1990). Paul also contributed significantly to the international activities for protecting the ozone layer (i.e. the Montreal protocol and its amendments and adjustments, see WMO, 2022, and references therein).

Thanks to Paul, John had the pleasure of travelling with Paul and reporting about atmospheric remote sensing opportunities for Germany to a formal meeting of this Commission at the Ministry for Science and Technology in Bonn. They had the Dornier Company (now Airbus), as the prime industrial contractor on hand to demonstrate the technical feasibility of the proposed concepts.

The Enquete Commission of the German parliament in its broad ranging report (Schmidbauer, 1990) made important statements about the value of remote sensing for atmospheric research. The German Research ministry (BMFT) under Professor Dr. Heinz Riesenhuber used this advice and created its ATMOS programme, including support for SCIAMACHY nationally and the Earth Observation programme of ESA. In 1986, West Germany was alone responsible for more than 10% of the tropospherically long lived ozone depleting substances (Dickman, 1988), which were primarily chlorofluorocarbon compounds (CFCs) and halons (WMO, 2022). In more detail, the global consumption of CFC-11 (1976-1986) was 300±50 kt/year, of CFC-12 (1976-1986) 350±50 kt/year. In the European Union, production of CFC-11 and CFC-12 together (1976-1986) amounted to 320±20 kt/year, while the EU production in 1986 was: CFC-11: 204 kt; CFC-12: 168 kt. In Germany, consumption (1980s; all fully halogenated CFCs) was 60-100 kt/year (Schmidbauer, 1990, p. 181 ff.). Note that consumption and production figures are not comparable since the latter also include exports.

The release of ozone depleting substances and halons to the atmosphere resulted in a global depletion of the stratospheric ozone layer and the appearance of an "ozone hole" over Antarctica in the Southern Hemisphere springtime polar vortex, first reported on the basis of ground-based measurements by Farman et al. (1985). Consequently the SCIAMACHY and SCIA-mini proposals were timely.

3.3.5 Paul as an advocate for atmospheric remote sensing from space

Paul first exploited NASA (National Aeronautics and Space Administration) 4 BUV (Backscatter Ultraviolet) ozone measurements to show the impact of solar proton events and the production of oxides of nitrogen on stratospheric ozone (Solomon and Crutzen, 1881). He was a PI and advocate for the NASA Halogen Occultation Experiment (HALOE) on the Upper Atmosphere Research Satellite (UARS), which was launched in September 1991 (Russell III et al., 1993; Crutzen et al., 1995). He gave

John the following advice for SCIAMACHY namely that one needs to be careful to keep space experiments well focused and to be realistically manage expectations. He liked to call SCIAMACHY "Sky–magic".

SCIAMACHY was proposed in July 1988 for the ESA polar platform, later renamed Envisat. In December 1988 the SCIA-
175 mini, which was subsequently descoped and renamed GOME (Global Ozone Monitoring Experiment) was selected for a fast track launch on ERS-2 by ESA (Burrows et al., 1999). Paul coordinated the modellers, who supported the proposal and joined the science team. He was excellent, possibly unique, at facilitating science. It would not have been possible without Paul to win these game changing space missions.

3.3.6 Paul as a mentor

180 Paul was a great mentor. He was modest by nature and once told John Burrows late in his life that he learned a great deal from George Witt and Bert Bolin his supervisors at the University of Stockholm. He said they recognised some aptitude in him (Müller, 2022; Fishman et al., 2023) and then unselfishly facilitated his scientific research. This was how he later advised and guided the large number of scientists, who worked with him. In early 1991, Paul came to John's office and said that he should apply for a vacant position at the University of Bremen, the advertisement for which Paul just had received. He said he
185 thought that this was a good opportunity for John and also would provide the continuity for SCIAMACHY, as the University of Bremen wanted to build up its natural sciences. This initial discussion then led to John's later move to Bremen in 1992.

Paul remained a great support for the exploitation of space based instrumentation for atmospheric science and John had the good fortune to have many happy times with him and Terttu in the years that followed. Paul was an outstanding mentor and somehow things happened, when he was around.

190 ### 3.4 Ruprecht Jaenicke remembers

Ruprecht Jaenicke first met Paul Crutzen at conferences in the early 1970s. They also met at the well known "Dahlem conferences" in Berlin in the 1980s (Fig. 3). During Paul's time at NCAR (section 2), Ruprecht was visiting Boulder and was invited to Paul's house several times.

In Mainz, at MPIC, Paul Crutzen did not have an easy start. He was proposed to the Max-Planck-Gesellschaft (MPG) by
195 Christian Junge as a director (section 2). The experts opinions on Paul Crutzen were very positive, but somehow the MPG had problems appointing him. Maybe it was Paul's unusual career (Crutzen, 1996; Müller, 2022; Fishman et al., 2023).

Paul came to an institute (the MPIC) with collegiate management. He became the general director when he joined the institute. As the general director, he was responsible for all decisions on the entire personnel of the institute. During this time, a severe problem with the electronic workshop of the MPIC surfaced. The technically excellent head of this workshop also
200 developed instruments and displays for the company "Porsche" (and he also drove cars of this company). He had done the work at the MPI electronic workshop. That was the beginning of the digital area in this field. The head of the workshop was eventually dismissed, but there was a long lasting considerable unrest in the institute. This was a difficult staff issue but Paul supported by his co-directors managed the issue very well for the benefit of all.

Standing, left to right:
Reinhard Zellner, Ruprecht Jaenicke, Stu Penkett, Frank Arnold,
Pat Zimmerman, Hiromi Niki, and Franz Meixner.

Seated, left to right:
Ralph Cicerone, Paul Crutzen, Sherry Rowland, Mario Molina,
and Donald Hornig.

Figure 3. The Dahlem conference in 1982. Group on tropospheric aerosols and photochemical reactions. Participants as indicated on the image. (Picture courtesy of S. Penkett.)

Paul wanted to work with PhD-students. The chemists of the University of Mainz at that time regarded the trace constituents of the atmosphere of negligible scientific interest. The chemists recommended only PhD-students of moderate ability to undertake research on these substance. Christian Junge also suffered from this problem. At the MPIC, there was the chemist Peter Warneck, who was assigned to Paul. Peter Warneck was an outstanding scientist [2] who had habilitated at the University of Mainz and was therefore permitted to lead doctoral students to a PhD. Peter Warneck and Paul oriented themselves more towards the Institute of Atmospheric Physics, because of the reservations of the chemists at the University of Mainz. Warneck regularly gave lectures on the chemistry of the atmosphere. at the University of Mainz. Paul Crutzen also proposed giving lectures. But the Dean of the "Fachbereich Physik" (the Institute of Atmospheric Physics was part of that "Fachbereich") at that time, was very formal and strict. Paul Crutzen had a PhD but but his "Filosofie doktor" was not accepted as being equivalent to a habilitation. So the Dean addressed him as "Dr. Paul Crutzen" in letters and not "Prof. Dr. Paul Crutzen". This was in spite of Paul being appointed to a Professorship at the University of Chicago and later at University of California at San Diego.

[2] https://www.mpic.de/4388946/nachruf-prof-warneck

There were a lot of discussions and problems getting Paul appointed as a professor of the Fachbereich/University and thus being permitted to lead students to a PhD at the University of Mainz. Only shortly before Crutzen was honoured with the Nobel Prize that goal was achieved and Paul became a "Honorarprofessor" at the University of Mainz. Interesting to note, because of his many obligations, Paul never gave regular lectures at Mainz; he lectured a few times and colleagues stepped in to give lectures.

Paul Crutzen proposed that Ruprecht should write a comprehensive article for the Landolt-Börnstein (Jaenicke, 1988). And years later Paul proposed Ruprecht for an oral presentation in Cape Town as part of the process whereby the city of Mainz became a member of the "Great Wine Capitals". Both proposals Ruprecht followed with enthusiasm. They demonstrate the excellent relationship Ruprecht had with Paul.

3.5 Rich Stolarski remembers

Back in the 1980s, Rich Stolarski, the famous atmospheric modeller from NASA Goddard Space Flight Center, visited Paul in Boulder. Rich enjoyed the interaction with Paul and was a frequent visitor to Mainz in later years. In the 1980s, Paul had agreed to let Rich have a copy of the code of Paul's 2D model. Paul generously shared his results and coding. Paul had a printout of the code that he said he needed to go over with Rich so that Rich could understand what Paul had done. They retired to a room where Paul started to go over the code line by line. Rich began to understand why Paul needed to go over the code. Paul did not waste time cleaning up code and improve comments. The code was not easy to read with seemingly random insertions and cryptic comments like "there seems to be too much diffusion in the upper stratosphere so... $K_{zz} = 0.5 \cdot K_{zz}$". Rich took the punch cards for this code back to Goddard and messed with it for a while but eventually gave up because he just could not get anywhere with it. Looking back on this story, Rich remembers the lesson that he learned from that incident. Paul was not a very good programmer. Many wrote better codes. But Paul was an artist. He wrote codes to test ideas. For him the code was not the goal, the idea was the goal.

Rich would say, modestly about himself, that he succeeded in writing some imperfect code and even had a few ideas. However he considered that Paul's genius was not just ideas, but lots of ideas that he could string together into a whole picture. Over the years Paul went from one picture to another always with ideas that he knew how to pursue and figure out their implications. He went from mesospheric chemistry to stratospheric chemistry to tropospheric chemistry to aerosols and to the Anthropocene (section 1).

Going back even farther, Rich remembers going to an AGU meeting in San Francisco where there was a session on the impact of supersonic aircraft on the atmosphere. If he remembers correctly it was 1970. At that time, Paul was a complete unknown. He gave a talk on hydrogen oxide chemistry. Rich remembers him getting up and showing a viewgraph with a lot of chemical equations on it. It came up out of focus but Paul said that was okay because he was just trying to impress the audience that he had a lot of reactions in his model. Rich liked his humble attitude and desire to determine if any of his work might be of use on this problem.

A few years later (in 1973) Rich Stolarski gave a talk on chlorine chemistry at the IAGA meeting in Kyoto, Japan. (this talk later led to the well known paper on the impact of chlorine chemistry on stratospheric ozone, Stolarski and Cicerone, 1974).

Figure 4. Paul Crutzen and Mario Molina listening to Christos Zerefos playing the piano at the opening of the Quadrennial Ozone Symposium in Kos (Greece) June 2004. (Picture courtesy of R. Stolarski.)

Ralph Cicerone and Rich Stolarski had gotten on to the idea from, among other things, talking to Don Stedman who declared that "chlorine destroys ozone, everyone knows that!". After the talk Paul sat down with Rich in the hall and went through a series of chemical equations that Paul argued might actually lead to an *increase* in ozone. He later said that he wasted several months trying to prove that chlorine could increase ozone. Looking back on it Rich thinks that Paul did not waste his time because what he was really doing was being thorough and proving to himself that nobody had made some dumb mistake. In fact Rich and Ralph (Stolarski and Cicerone, 1974) had made at least one simple omission in their line of arguments that was pointed out by Doug Davis; they had not initially included the formation of HCl. Years later they were doing Monte Carlo uncertainty calculations and it turned out to be within the realm of possibility that chlorine could increase ozone if the reaction rate of $OH + HO_2$ was extremely small. In that case HO_x would have very large concentrations and dominate ozone loss. Chlorine would then catalyse the reaction $OH + HO_2$ via $Cl + HO_2 \longrightarrow HCl + O_2$ and $HCl + OH \longrightarrow Cl + H_2O$. This, of course, was not so because the reaction rate for $OH + HO_2$ turned out to be much greater than for this extreme case (as it is known today, Burkholder et al., 2019). It does show that in those early days it was quite reasonable to test the idea that chlorine

might cause an increase in ozone. Paul was all about testing ideas, of which he had plenty. Paul and Rich met many times over the years, one occasion was the the Quadrennial Ozone Symposium in Kos (Greece) in June 2004 (Fig. 4).

3.6 Rolf Müller remembers

3.6.1 A PhD in Paul's department in Mainz

As discussed above (section 3.4), the relationship between Paul and the University of Mainz was not always easy. But after receiving the Nobel prize in Chemistry both the Max Planck Society and the University of Mainz were very proud of Paul and his scientific achievements. On one occasion the president of the university brought up Paul's Noble Prize in a speech, mentioning the University of Mainz many times. Paul was listening, while standing next to the "Kanzler" (the financial and administrative head) of the University of Mainz. The latter mentioned to Paul quietly that perhaps there was a bit too much mention of "our university" in the President's speech. Paul replied wisely and humbly (in German [3]) "that in any case what counts is the future (i.e. rather than the past)!".

Paul was travelling a lot and people at his institute developed the habit of putting important papers and documents on his chair in the office, so that he would find the important material immediately upon his return. But there were too many important things so when Paul returned to his office, he frequently found a considerable pile of documents on his chair. The concept did not work; Rolf Müller was present, when after days of absence Paul returned to his office, moving the entire pile on his chair somewhere else (without paying attention to it) and then sat down in his chair starting a scientific discussion.

On one occasion, Paul asked Rolf and colleagues for the model results (and the plots) for a particular problem in Antarctic ozone chemistry (indeed the plots for the paper by Crutzen et al., 1992). The plots were not ready and Paul was informed about the circumstances. His reply was that he needed the plots urgently to finish the paper. The response was how could he finish the paper if he had not seen the results and the plots. His response was (with some self-irony) "I know the outcome of the simulations, but I need the plots for the paper". Paul was always impatient to receive information on new scientific results (and this included being impatient with himself) – this anecdote is an example of his impatience regarding new scientific results.

Paul was always working, but sometimes, he put aside a few days of holidays for his family. And he had an agreement with his wife: he would not take any work along on his holidays. With one exception: one (but only one) piece of work he was allowed to take along on holidays.

3.6.2 A talk in Jülich in February 1996

In early 1995 Rolf Müller moved from Mainz to Jülich, he got a new job at the Forschungszentrum Jülich. He thought it was a good idea to invite his former boss at Mainz for a seminar, so a plan was made for February 1996 (one had to plan months in advance to find a time slot with Paul already at these times). Seminars were on Thursdays in the afternoon and the seminar was fixed for Thursday, 15 February 1996. Soon thereafter two things happened: First, Paul Crutzen (together with Mario Molina and Sherry Rowland) was awarded the Nobel price for chemistry in 1995. Second, it turned out that 15 February 1996 was

[3] His words were: "Auf die Zukunft kommt es an."

"Fettdonnerstag" or "Wieverfastelovend", which is *the* day when carnival is celebrated in the region at the place where you work. (Mainz, the town in which Paul lived at that time is also a carnival town, but this tradition was less intensively nurtured there.) On "Fettdonnerstag", people would be at work, mostly in carnival costumes, and (definitely after 11:11 in the morning) would not work, but rather be in party mode.

There was a big commotion at Jülich. The board of directors did not dare to officially welcome the new Nobel Laureate on such a day. However a shift of Paul's visit to another day was not a feasible option either. In the end, it turned out that the big lecture hall was full of people (some in costumes) listening to Paul's talk on the impact of halogens on tropospheric ozone. But what happened was that after Paul had started his lecture for a few minutes, the door swung open and a band of "witches" came in with a big pair of scissors. One needs to understand that the "witch" is the traditional women's costume on this day and that women are allowed (only on this day) to cut the tie of a man. But Paul did not wear a tie on this occasion. He continued his talk after about five minutes with the words "I hope I will be able to focus on my talk again now".

4 Summary

Paul J. Crutzen was a brilliant scientist. And whilst he enjoyed his research successes, he was a modest man. Up until the end of his life, he was motivated and fascinated by new challenges and ideas in the atmospheric sciences and the role of humans in determining the behaviour of the earth system. His focus was not on his past achievements and Paul was not only a scientist, but also a kind-hearted, humorous and pleasant person. Something that cannot be said about every great successful scientist. He was interested very much in the private lives of his colleagues and students and he had always time for his family. This collection of anecdotes and recollections offers a glimpse into the human side of Paul Crutzen, an aspect that often remains hidden behind his many outstanding scientific accomplishments.

Data availability. not applicable

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