AMS Kuettner Symposium January 19, 2010

Jay Fein:

Thank you. Before I welcome folks who've come here today, I want to say good morning and say welcome to our colleagues at Boulder, Dr. Kuettner, Monika, colleagues from NCAR and from the Boulder area, and friends who have come to Boulder, to our "second operational site" for this "project". Joach swore that he would never, ever lead a multi-hour operational site project again (laughter) after several of them that were very, very complex, and here we are doing it one more time. To the people here today, a very warm welcome for coming. The topic of today's symposium, as you well know, is Winds Over The Mountains: A Remarkable Man's Love Affair with Flight and Mountain Waves, and it's a special symposium in honor of Dr. Joachim Kuettner.

Rick Anthes:

Welcome, everybody. I have a few slides which are almost picked at random from Joach's distinguished career, and I must say it's an honor to kick this symposium off. I've had the pleasure of working for Joach for 15 years, nominally as his supervisor but, as Jay says, much more as a mentee or a colleague. I'm not going to go to full screen for my presentation because if I go to full screen, the presentation automatically cycles through with five seconds between slides. Maybe somebody's trying to tell me something (laughter).

Just to remind you, Joach was born over 100 years ago in Breslau, Germany. (We had a 100th birthday party for him last October at NCAR, which was well attended and was quite a success.) Some of the pictures I will show are in your book, but I guess it won't hurt to see them again and in color. This is Joach when he was three years old. And here is the mountain observatory in the Alps where Joach became chief of the observatory in 1945 and held this position until he came to the U.S. in 1949. Now, wouldn't you like to commute to this place every morning and carry out your day's work? What a place to work! Here's a favorite picture of mine, Joach and Monika's wedding photograph on August 3, 1949 -- I think this is also in your book.

Of course, one of the many thematic areas where Joach is world famous is his work with mountain waves and his observations of mountain waves from gliders; this spectacular picture is a mountain wave near Bishop, California. It was taken before the 1950 Sierra Wave Jet Stream Project, which was one of Joach's earliest field programs in 1950.

I mentioned that Joach holds many glider records, and others will speak more of these records, so I won't go into them in great detail. But here's a picture of Joach and Harold Klieforth in a glider that was used in the Sierra Wave Jet Stream Project. Joach published many reports and books, and this is just one, which is a set of research notes, *The Rotor Flow in the Lee of Mountains*. I think it's fair to say Joach was one of the scientific pioneers in observing and understanding rotor and wave phenomena.

Others will talk in some detail about Joach's experience with the early parts of the space program. Here is an introduction – a picture with three astronauts standing in front of the Mercury Redstone Rocket.

I turn now to the GATE experiment. GATE was a very complex international program, especially considering the relatively early year of GATE. GATE occurred in 1974 and was one of the most complex field programs ever carried out: 70 nations, 40 ships, 13 aircraft, and 4,000 people participated in this program. I like this photograph – maybe Ed Zipser or others actually remember this, but here are three ships tied together – a West German ship, a U.S. Navy ship, and an East German ship. This was during the Cold War, so they had to have a bit of a diplomatic protocol system set up. As I understand it, the U.S. ship was the "Checkpoint Charlie," and they charged one beer per person to cross from the East German ships to the West German ships. (laughter) It was very civilized, and we could all learn from that solution to a diplomatic problem today.

This photo shows Joach and Karyn Sawyer conferring at the Kuettner Symposium at NCAR in 1994, 15 years ago. And this one shows Joach and Monika at his 85^{th} birthday celebration at the NCAR Mesa Lab. And this one is of Joach ferrying from Mali to Kaashidhoo – I'm not sure I'm pronouncing that right –

Climate Observatory in the Maldives during the INDOEX experiment. The Kuettner family in 2004. Joach and Ram planning the Global Albedo Project in 2005. As you see, this slideshow has already spanned almost 100 years. This 2006 photo shows Joach and Carlye Calvin, who is here today running our projection equipment, in the California Sierra Nevada range as Joach returned to the Sierras. And these, the flip sides of Monika's original artwork honoring Joach's 100th birthday, September 2009. The black and white version of Monika's art is in your brochure.

And bringing us almost up to the present, this photo is from Joach's 100th birthday party, held October 3, 2009 at NCAR. Here is his birthday cake, and this one of Joach giving the concluding speech at that wonderful celebration.

One of the things I liked about my meetings with Joach was that they were not very formal. For example, he waved me into his office one dark winter afternoon about 3:00 and said, "Sit down, Rick, I have something for you, for us." Then he brought out this bottle of Goldwasser, which was strictly against all UCAR policies. (laughter) You have to have alcohol permits, and you can't bring your own liquor in. But he had this bottle, and nobody was going to tell a nearly 100 year old – at least I wasn't – to stop, or write him a disciplinary letter, (laughter) especially since he was sharing it with me! So anyway, it was very civilized, a tiny little thimble of this wonderful liqueur with flakes of gold, and chatting about what we were doing.

I always enjoyed meeting with Joach because when he would come in to my office to show me what he was doing, first he would ask what **I** was doing, and we'd talk a little about that, and then he would eventually get around to what he was doing. He always put others first.

This photo is the picture on the front cover, and it is indicative of just the way Joach is: philosophical, gentle, kind, curious, inquisitive. And the traits have, I'm sure, contributed to his longevity. So enjoy the symposium, and Jay, I'll turn it back to you. (applause)

Hans Volkert:

First of all, while the slides are building up: “Lieber Joachim! Ich gruesse sehr herzlich hinueber nach Boulder und freue mich sehr, Dich munter und in Uebergroesse hier auf der Leinwand zu sehen [Dear Joachim, I send heartfelt regards across to Boulder and I am very happy to see you agile and in ’over-size’ on the screen here]”.

And now for the benefit of all the others I better change to English. Good morning, ladies and gentlemen. I want to invite all of you to join a thought travel across the Atlantic and some 70 years into the past. My aim is to recall Joachim Kuettner’s achievements as a young atmospheric scientist after he had decided to abandon a career as an attorney or a judge at regional courts back in 1934. Hence my word toying expression, “Searching for Law in Disorder.” (laughter)

The perhaps pretentious subtitle, “Detecting Waves and Rotors Through Intuitive Multi-disciplinarity” joins together three strands. First, the features of waves and rotors at the lee side of cross-mountain flows. Then, the fact that Joachim contributed heavily to their detection and documentation. And finally, my hypothesis that already in his early achievements he much benefited from his manifold talents. I will borrow from legal terms occasionally, as Joachim started off studying law and being a lawyer, and will attempt to present a convincing pleading at the end.

Here you see the major crime site, so to speak. It lies in the air above the Riesengebirge with altostratus at the bottom, at the upstream side, and then spilling down in an airflow perhaps to broken cumulus downstream at the lower levels where rotors may be hidden – Vanda Grubisic later will tell us all about that – and strange looking clouds high above; we may think that there is a wavy pattern on that. This picture was taken in November 2008. It is on the backside of a European Meteorological Society calendar of this year, and the glider pilot Carsten Lindemann took it. This was re-inspecting the site some 71 years after a big field campaign to which we’ll come later.

Now, let us get our bearings first: here is America, it may be useful to point out how it looks like in Central Europe. Here, we have Breslau, then Germany, now Poland [Wroclaw], and the Riesengebirge and other cities – Darmstadt where Joachim started doing meteorology and then Hamburg where he finished his studies, and other places. Munich – he was there at the university before he decided to come to the U.S., after working on Zugspitze. You've already seen this mountain down here. Then Geneva as the operation center of ALPEX, and Innsbruck, if I can correct Jay a little bit, as the operation center for MAP. And you see here are the big Alps, and this minute Riesengebirge. The picture we saw before had its perspective looking that way and the airflow going that way, a long fetch, and then a tiny little hump, so to speak, 20 kilometers wide this direction and then 10 kilometers that direction, perhaps only 1 kilometer high, but it can exert waves, which Joachim documented.

After the general bearings we have to look to the usual suspect. His life was quite ordinary. It started with his birth in Breslau, was then followed by school with 'Abitur' at a 'Realgymnasium'; and then his first degree after just three years or six semesters, you know. Dr. jur, a law doctor at the Breslau university after studying law and political sciences; and then for three years he was working at law courts in a small place, Bad Landeck near Breslau, then in Frankfurt am Main, and in Breslau itself. But then suddenly an abrupt change came along to the quite outside-ish second study of meteorology. But not only that, it was combined with a semi-professional sporting activity as a glider pilot, mainly in Scandinavia with expeditions to Finland and then a year later as a member and then – I think the natural position which Joachim always liked to have is 'head of something' – the head of the German Aero-Club gliding expedition to Sweden and to Norway. But then he took his studies seriously, returned to Germany and changed to Hamburg, and with Professor Raethjen he resumed his studies. He gave a lecture, which was also published, in Berlin, and a year later, at less than 30 years old, he got his second Ph.D. Well, just as a little aside – we are often talking of progress, everything getting faster; this is not always the case. You know, some people long ago were more effective and efficient than people can be nowadays.

So, where do I get this information from? You know, the evidence here is not forged. I extracted it from an old document produced by the suspect himself. It is the printed version of a nicely formulated curriculum vitae at the end of his meteorological dissertation, and I was given that by the Chief Librarian of Hamburg University Library last summer. A few details in color, but we do not have to read all that. Here was his birth, he did the law studies, and he went to meteorology (in red). He did the “Fliegerei,” which is aviation, or literally “flying.” He was a flying instructor. He took part in soaring flight expeditions, and then he changed to Hamburg, to the Hansische Universität Hamburg. Good advice for any graduate or Ph.D. student is: “During the study course you just do two publications before your dissertation.” One was about aerology data in Lappland, North Finland, and the other one deals with material from the slide show.

Let me proceed to the full amount of the published evidence, and this is what I would like to call a “surge of uplift publications” in just three years from 1938-1940. There are no less than six publications, and four are given in red, because they are extended ones. Two are smaller notes, but they have all one common theme: Where is uplift in the atmosphere, which can be used for gliding? As a sporting or adventure type of thing, and then just also saying, how can we explain that? Joachim always had these two things in mind. There was an aim for his sporting ambitions, and perhaps extracting even pleasure and satisfaction out of that, which many people share, but the exceptional thing was: you go on that you want to explain. “I want to understand how it works, what brings the things together.”

While I could read through all the titles, it would take a little too long. Here is the Lappland stuff – it’s in northern Finland – then you see the account on the “Moazagotl wind” with many, many figures. This was his dissertation; it is a printed 49-page article in a journal, in the form of an extra reprint with an extra title page and the CV at the end. The Dean applied to get it certified. The Dean at that time happened to be his supervisor/professor – very practical, very efficient and quick – Paul Raethjen in Hamburg. But then there was another paper, about cyclogenesis and tropopause levels. You know, you have uplift not only at mountains, but also uplift at certain synoptic systems, and that's what he wanted to see - always with a look on gliding matters. It is amazing if you put it all together. There are 150 printed pages in journals with – and I think this is a record – a very extraordinary number of 56 black and white, brilliant photographs collected from many, many people in many countries, and 65 diagrams of quite some detail.

What I want to do now – this is the summary slide – is to give you a few examples, but they are all in the published literature. Perhaps we should discuss with Rick whether these papers are in the UCAR or NCAR library; if not, you better get them and have a look at them. Unfortunately, they are in German, but I think it doesn't hurt to read something in a foreign language. We have to do it every day. (laughter)

Here is just one example from his first one, the Lappland paper. It was old material of 1933, before Joachim got there – he was still at the law courts at that year – but very nicely depicted. It is called "Serial Assents" in the arctic air. It concerns the afternoon soundings. You have here the temperature profiles up to 700 millibars, for instance. You have then a cumulus condensation level. You have the dry adiabat at lower levels and the moist adiabat for comparison, in a meticulous drawing, of course. I guess it wasn't done by Joachim himself, but he could persuade technical staff just to get the things very compact from the data which he could collect from the people in Finland.

Let's continue. This one is from publication two. I think this is a very famous depiction. What you see is basically a map as reproduced from an atlas. Here we see height levels from 500 meters to above 1,400 meters of the nice little Riesengebirge, which we saw before — 20 kilometers this direction, 10 kilometers this direction, and a kilometer high compared to the surroundings. And then he said, you have an airflow from this direction coming south-southwest with 20 meters per second, and afterwards very regular zones of: uplift, downdraft, uplift, downdraft, uplift, downdraft. You can't really believe that this is true, it looks too nice. And he claims: 8 kilometers is the wavelength. So how could he come to this dream figure?

Here is the dream figure again, and this is a schematic sort of barogram from a glider. A glider is soaring in a wave and it has a normal sinking speed, but you can subtract this sinking speed and - finally - you get downdraft, updraft, downdraft, updraft over time, and with a conversion from time to space with the speed of the glider, you can come up with this: You go up, you go down, and with a certain wavelength. During a regional gliding competition on this particular day, the 21st of May in 1937, he had 22 workable barograms from competitors. He did not participate, he went around afterwards asking, “You give me your barogram - I collect it.” How he determined the locations, I couldn’t work out. This is not really explained in the text, but I think he had some good hints to that. And imagine that – have you ever had a field campaign with 22 aircraft at the same time in a limited area? I think this was something that was achieved straight at the start, but not since then.

Now, finally, a lawyer is producing all these sketches – he said to himself: “Let’s have cross-sections, this way or that way,” and that’s what he got: A to C are these ways, and I, II, III in Roman numerals are these directions. It’s a little hard to see. I’ll take this middle one and make it a little larger – this is number two here – here you’re upstream, you have the Riesengebirge, it goes downstream, and very extraordinary – this is the glider pilot’s perspective – it’s aspect ratio 1:1, one kilometer in the horizontal direction is equivalent to one kilometer in the vertical direction, which we don’t have today in our figures. Waves always look so exaggerated these days because we compress the horizontal directions or exaggerate the vertical ones. Here is the basic determination of the upstream stream lines. Another one, you see the cloud, the Moazagotl cloud, on top of it. The little circles here are the rotors. This will be Vanda’s subject after lunch. This is a very, very nice and important aspect: If you look just to the details, how it was done, meticulously done in the pre-computer age. I find it fascinating.

Now, we go to his dissertation, where he was obviously asked – his main forte, I would say, is observations, really good observations – to put them in perspective, for explanation. And I would clarify: He came up with a conceptual model of the mechanisms of this upstream airflow over the mountain in higher levels and in very high levels, and he would say and then argue that it supports bore-type flow aloft. You have – it's coming along, it goes down – at the end the surface is higher than upstream, which is an analogy to a very famous classical example from 1886, when Lord Kelvin was doing experiments in a water tank over an obstacle and over a depression. Joachim borrowed these figures just to get some ideas or make analogies between the streams in water and in air. In the middle you have just the trapped lee wave, as you would call it nowadays, and at lower levels you have in the fast shooting flow turbulence with rotors. But most important is always: Where are the zones of consistent uplift? Here's one, here's one, and you have this very significant feature. Well, they are not perpendicular, but the inclination is changing with distance. This is what Joachim has produced, more in a theoretical, conceptual modeling type of approach. There are some formulas, some calculations, as they were done probably with a slide rule, quite simple, no big three-dimensional models, of course.

But the big fact is he did not only stay with the Riesengebirge, he also collected an aerial photograph taken by somebody called Rau. It was taken at a level of 3.5 kilometers above Munich facing towards the Alps on the 24th of February, 1939, which is just two months prior to the acceptance of his Ph.D. thesis. He mentioned that, "I am having my Ph.D. finished, and I have informed everybody, if you make good observations you better give me your photographs, and I get it into the published papers and I get it to the dean in time so that this publication is accepted as my Ph.D. thesis all in two months." Well, he had to hurry up because the Second World War was starting soon after … but he didn't know that beforehand … it was tricky times.

Anyway, what do we see? We have the Zugspitze here. We have here the lake Starnberg (Starnberger See) that way. And he just claimed that the cloud layer, this very dark cloud was a really huge Moazagotl-type or bore-type cloud above the Alpine foreland - expanding from six to ten kilometers, and with the lateral extension of 250 kilometers, and the north-south size of 80 kilometers. This was just the attempt to say, “What I studied in detail at the little Riesengebirge also applies – if the synoptic conditions are suitable – to big mountain ranges as the Alps.”

Now, these were the examples, and before I’m going to let our defendant have his last word, being comprised of three very pertinent quotations, I will plead to you now, my today’s audience and jury, so to speak. Joachim Kuettner, I think, personally interfered with atmospheric action as a record breaking glider pilot;

- and returning to the ground he found and documented important connections through physical laws between many pieces of the observed evidence within a seemingly chaotic or disorderly medium - the atmosphere around us;
- he could do so because he applied his law searching experiences to the atmosphere;
- he was able to secure the appropriate funding, probably also by self-exploiting him as a laborer; and
- he knew how to motivate many others to work for a common aim which he had pre-selected.

This is my opinion, my plea to you.

You may discuss later on and judge at the end, but now let us inspect what Joachim himself had to say regarding the themes “law versus science,” “funding,” and “teams.” In an interview in the bulletin of the WMO, Hassan Taba interviewed him back in 1989. He said, “I found the so-called science of interpreting human law most unsatisfying. The natural, physical laws were much more in my line.” And secondly, “Law is a domain that is strictly national. I saw no prospect of being able to apply my knowledge of German law to any other country.” So he had really always had the ambition to get to a bigger arena. Then second, where funding is concerned, at some stage he said in a private communication with Ulrich Schumann (at DLR) and myself: “Well, a system as Adolf von Harnack installed back in 1911 for the Kaiser-Wilhelm-Gesellschaft, which is now the Max-Planck-Gesellschaft, is the following: You just give a bulk sum of money to a good, knowledgeable person – in those years obviously a man; I don’t know whether you can do it at

UCAR, whether you do it like that, with no big fuss around – you just give the money to the persons that they should think how to work, and hire people and equipment”. And then he said, “By the way, this guy happened to be my godfather.” So he indicated that he was from the very start well connected and had experiences with people like that. I found this very astonishing.

And then, where the teams are concerned, in the BAMS you could read after GATE, “What makes us hopeful, then, is that scientific teams from many countries, bringing along a multitude of technical systems, speaking many different languages, having different scientific or political outlooks, and varying national priorities, they can, if they set their minds to it, successfully execute a highly complex observing system.” This was a good experience, and I think this is how international cooperation works at all. How am I as a German invited to speak to you here, and Joachim, you know, coming across the Atlantic 70 years back. I think this is something which we have to keep in mind, but the main thing is this:
“To the top! That’s the way, folks,” Joachim says, as depicted nine years ago at the Schliersee, at a MAP meeting (2001), explaining the famous Sierra Wave Project. He’s pointing upwards, and very elegant, gray suit, one hand in his pocket, and this was an example for us.

With this I will finish. I thank you very much, and I am looking forward to your vote as a jury. I’m happy to take any questions, even from Boulder. If this will not be the case, I have a little bit of a bonus material, how the situation looked in November two years ago, the Riesengebirge as seen from METEOSAT; and Rick may be happy to see also satellite observations of mountain waves.
Thank you very much! (applause)

Jay Fein:
Hans, thank you so much. Stay a bit in case there is a bonus that we get. I forgot to mention earlier that anyone at Boulder having comments or questions, I’m sure there is someone there with a microphone, and we would be happy to take those. Hans, address how you met Joach and how you interacted with him over the years? How was your first meeting?

Hans Volkert:

Well, the first meeting occurred when he was a guest scientist at DLR in 1981, which at that time was called DFVLR, with Manfred Reinhardt director. I was a Ph.D. student. I was introduced at the canteen, perhaps, at a coffee round to say hello, and then – unfortunately I didn't make it to Geneva to the famous bomb shelter gang of student helpers. But later on I think, he insisted that there had been no good cross-mountain flow in ALPEX, so we should try it again with a Föhn-project, and he came over to the ALPEX regional meetings saying: All in America, everybody there, especially at NCAR, they are so keen to do gravity waves or whatever specialized studies. Well, we didn't fully believe it, but anyway, he intrigued us in a way, and then Manfred Reinhardt retired and I inherited this position as the German coordinator for this ALPEX regional.

Later, during some committee meeting in Innsbruck (Jan. 1992), one suddenly didn't really know how to continue, and then over lunch break Joachim said: "Now we must have a working group, and where's this young fellow? Yes, he will be — he won't say 'no' — I think he should be the ad-hoc chair of this working group." And then a few years later it was MAP. And I was just, as many people said before, I was so intrigued, he took it earnestly, and you felt to be taken earnestly by somebody and a gentle, knowledgeable gentleman from the States speaking German with me and then telling me afterwards: "Well, come on, let's forget about the 'Herr Volkert' and so on … 'I am Joachim, you are Hans'" you know, and then saying 'Du' instead of 'Sie' - something special in German … and he set this example.

If you really want to have an anecdote: Later he visited Murnau, which is south of Munich, and he said – he telephoned – "We have to meet, we have to discuss the progress, and I have to tell you that all the Americans are even more excited than before about something like an Alpine experiment; I don't have time to come to DLR, but on the phone it's no good." So we ended up that we would have a kind of espionage meeting at a motorway rest station just in the middle. He drove up from Murnau, I drove over there. We just had a coffee, we talked for half an hour, three quarters of an hour, but this is

the difference, you know. Any leadership person should just take these lessons, you know: Make persons interested, get them involved, but probably you can't copy Joachim's method, you have just to be Joachim, and this is a little bit difficult if you are another person. (laughter)
I don't know whether this answers your question.

Jay Fein:
Thank you, Hans. Any other questions? Yes, Bob Grossman.
You need to come to the microphone. This sounds as though it's going to be longer than I can translate. (laughter)

Bob Grossman:
No, it's going to be very short. That in addition to the curiosity and the joy of adventure, which Joach mentioned, I just want to mention two other characteristics, and that was persistence and insistence. I think you all know what I'm talking about.

Jay Fein:
Thank you very much, Bob. Any other comments from Atlanta, or questions?
OK, how about Boulder? Anyone at Boulder like to say anything?

Joach Kuettner:
I want to thank Hans Volkert for the presentation he just made, not only in perfect English, much better than mine, but also he has probably given more attention to my publications than anybody else so far. (laughter)

Hans Volkert:
At least I tried to read it, Joachim, and I think your German is very nice to read even 70 years later.

Joach Kuettner:
Thank you. (laughter) Thank you very much for this nice presentation. I really enjoyed it, and it was quite correct from one end to the other.

Hans Volkert:

So are you curious to see what the Riesengebirge airflow looked like last fall? Here you get the bearings. This is central Europe. You can see a little bit of the North Sea here – there may be Hamburg. So this is on the 11th of November in 2008 at 10:00 Greenwich Mean Time. Here you see the North Sea, Hamburg. You have this big frontal band. It's roughly the map which I showed before. You see a little bit of the Alps here. This is snow covered, dark in the valleys. You see a lake that is probably "Chiemsee." and then you would have the "Bayerische Wald," you have then the Czech Republic, and here is the "Riesengebirge" going into Poland. I will advance it now 15 minutes to the next METEOSAT image, so I've just taken out this line and you see, it's a chaotic cloud, but there's this little sausage type thing. It's standing there persistently. Fifteen minutes later much is moving, so I go a little faster. You see even these systems here, they are moving. They are probably gravity waves in a way, as well. So this is back and forth, and this was just a poor man's loop. Now we go to a GIF loop which I cannot manipulate in speed, and it's just going here. This cloud here – meanwhile it's dark – now it's starting again.

This is the entire day, and then at sunset very, very high uplift. A very transient system, but it was well forecasted. The glider pilots, they know what to wait for. They knew it was coming two days previously. They went before to their planes, then Lindemann and others soared the wave. So, if you want to have more details, buy the European meteorological calendar 2010 and look at the back side of the November picture for all the details; and on the back side of September, I think, there's something about Joachim so it fits together nicely.

This was my bonus material. Any good film, DVD nowadays, has to have a bonus material, of course. (laughter)

Jay Fein:
Thank you. Hans, thank you very, very much. That was wonderful.

Einar Enevoldson:

I think I was a junior at UCLA when I took some time off and went to work, basically for Joach, at the Sierra Wave Project in 1952. It was an irresistible opportunity. I'd read the name in a book on soaring that was in my junior high school library in 1945 in San Francisco. I don't know if they have books like that in junior high school libraries anymore. The book talked about his early exploration of the mountain wave in Germany in a glider, not this one but pretty much the same kind of glider in those days of iron men and wooden ships. And then later in the war he worked as a manager and test pilot for the German industry, and fortunately for us, this immense airplane was not in service early enough to have much effect. I think we were lucky. It was intended for use primarily on the Russian front for heavy logistics, but it took too long to get it fully developed. It was a huge airplane, I think the biggest airplane in the world at that time. After the war, Joach came to the United States to be the Chief Scientist on the Sierra Wave Project. I think he's still wearing that same coat. (laughter)

Another wooden ship for the iron men: this is the type of glider they used in the Sierra Wave Project. I have two great memories from this project. One evening Joach was coming in to land. We were operating from an inconvenient part of the airfield, and we were waiting to push the glider to the hangar. Joach appeared overhead and came in to land a little differently than normal, and I would say – I would describe it as: it was practical, it was imaginative, it was elegant, it was graceful, and it was executed to perfection. We didn't have to push the glider. When he climbed out I thought, "Even an old guy like this can still fly pretty well." (laughter) And the other impression I had was the kindness and consideration and respect that I was treated with by Joach. He took care that I understood what he was explaining to me. It seemed important to him, and I was impressed, and I've never forgotten that.

Of course, at Bishop you see clouds like this all the time but I had not seen them before. This cloud set a trap in my brain, which sprung shut 40 years later in Germany when I was at the DLR working on the Strato 2C, just by chance walking down the hall. Wolfgang Renger had obtained this picture; it's a LIDAR, false color image. He had started in the Transall C160 using a vertical up-directed LIDAR. They started over near Sodanklya and flew west to Norway looking up, and this was the backscatter picture. I looked at that and in about two minutes with a ruler and a protractor I said to myself, “I could be soaring up here at 23 kilometers, and probably a lot higher.” There just happened to be no particles up higher for the LIDAR to reflect from.

So with that I saw that I had no choice. My destiny was to chase that cloud, and I started the Perlan Project: the name comes from the name for the mother of pearl clouds. These were taken from Kiruna in northern Sweden. Starting the project really meant looking for money, and trying to understand more about the possibilities for actually flying in these waves in the stratosphere. As far as the money goes, I eventually found Steve Fossett, who put up the money, and we bought the glider and prepared it. Amazingly enough, NASA loaned us pressure suits and furnished meteorological help and an instrumentation engineer. We prepared the glider for flight with the pressure suits. Flying the sailplane in pressure suits wasn’t too practical but was doable. We did some shakedown flights in California City and discovered, among other things, that our destiny was to spend our winters in cold, windy deserts. We’re always in the rain shadow in some cold, windy place. We went three seasons to South Island, New Zealand, where we had a wonderful reception and lots of help. These were very nice campaigns, but we never made contact, and the conditions were never quite right, so we got to looking at a world map of stratospheric winds. This is prepared by Elizabeth Austin. I don’t know if she’s here or not. Ah, there she is! And so we looked at this and we said, you know, this is kind of typical. The polar vortex or the stratospheric polar night jet is a little south of New Zealand. Although it does come up there sometimes, we have a little better shot at it in South America. You can see that if you want to go south, where there are some mountains, there’s only one place on earth to do that, in the southern tip of Argentina or Chile. You can see another thing, that New Zealand is angled off a little bit, it’s not straight north-south, and the winter winds tend to go around Tasmania and come up obliquely against the Southern Alps. Later in the spring season, the winds come more from the Northwest, and they have excellent waves, but by that time the night jet has gone away for the year. So our prospects looked a little better in South America. We chose the place El Calafate, not being too sure whether we had logistical means to operate there or not, and another cold, windy desert – cold! Logistically, we put all our equipment on a flatbed truck and went 96 hours south from Buenos Aires. But we had a wonderful big international airport where they didn't have much traffic, and they gave us full run of the place. Here we are out on the main runway with our glider and our tow plane. There we are towing. This is a picture that the tow pilot took – towing us up the lakes and into the Andes. Then we cast off over the Andes at about 10,000 or 11,000 feet and went up from there. This is when it really gets to be one of the great experiences. Flying these magnificent waves, because we're sitting here amongst these absolutely incandescent, massive, beautiful, stacks of lenticular clouds, and we're going up on the order of eight to ten meters per second up through 35,000 feet. The views are certainly worth the price of admission.

So we succeeded in getting up 51,500 feet. That's just a picture to show the air brakes. Joach had told me an experience they had in the Sierra Wave Project where due to differential contraction of the structure and the linkages in the cold they couldn't open the air brakes. That would be a very serious problem because a glider simply will not come down fast without air brakes. And they had quite a dangerous adventure dealing with that. So I had taken great pains to make sure that these air brakes would always open, and I overdid it somewhat. They opened voluntarily and became an automatic altitude limiting device, but even with that we were able to get up. I won't talk too much about the flight except I will say our altitude was limited by practical matters. There's still a lot of wave there, and it probably was getting stronger if we'd stayed to go higher, but the difficulties were all of a practical nature. In particular, we couldn't see our displays because of the extreme glare, and we couldn't steer the airplane too well because the pressure suits inflated and restricted the controls. As you go higher the pressure inside the suit remains constant, and the outside pressure gets lower, and the suit gets stiffer. It was getting pretty stiff and becoming marginally acceptable for controlling the airplane. So at that point we decided we had achieved the goals of phase one, which was to demonstrate the concept. I'll explain in a moment what I mean by that. In this case, this shows that we succeeded in coming down in one piece. That's our team. It was a great team, and we needed all of those people.

Here's another graphic from Elizabeth Austin, and I'll explain it a little bit. Here's the Equator, and here's the South Pole, and here's ground level, and here's about 100,000 feet, and these are wind cross-sections. This is sort of like looking west at a big plane. This is at the moment we were flying, and that's where we were, 50 degrees south and 51,000 feet. What it shows is the night jet was pretty close to being directly above us. It was not a terribly strong night jet – on the order of 140 knots. I think these are knots. I can't remember. They could be meters per second, but I think they're knots. You can see the subtropical jet and maybe a little bit of a polar jet. We don't quite satisfy the ideal conditions for a wave to propagate vertically, that being that there be no minimum of wind speed – that it increase continuously as you go higher. We had a slight minimum, but it was a weak minimum, and it did not prevent the propagation of the wave.

This is an animation, and somebody here may know better the history of this animation than I do. You can see here are Greenland, Spitsbergen, and Scandinavia. We're looking down from space at the Northern Polar Region, and it shows the evolution of the night jet during a winter season. And there the night jet's starting up in the early winter, and it wanders around and changes shape, and then it quits in late winter sometime. Like I said, I don't know the reality of that, but it certainly fits my image of what the night jet looks like. Now, there's another one on the South Pole in the southern winter, and it extends out a little further from the pole; it goes out maybe to 50 degrees latitude whereas the Northern Hemisphere one seldom gets much below 60 degrees latitude. That's a big advantage because the ground conditions for working are much more friendly a little further from the pole. In the winter you get some daylight while in the Northern Hemisphere you get very little if any daylight. So that was very nice for our initial explorations of flying into the night jet.

Here's a very simple model, a linear model of the conditions at the time we were flying, and here we are in the Pacific Ocean – coming across to the

Andes and over to the Atlantic, and ground level and 20,000 meters, and this was computed from a 36-hour prog, and that's what the linear model showed. Even though we had quite a bit of moisture in the atmosphere that day, we'll see how the flight went. If you've looked at many of these things, you'll be aware that it's a very common configuration where you get a primary wave here and then it may weaken at some higher altitude. Then you get a field of secondary waves, some propagating higher than the primary. So where did we fly? This is our GPS track that we actually flew in the glider. You can see that it was pretty much where the simple model predicted. There's also a full physics model of the same condition which looked quite a lot like this. The physics model showed wave breaking a little above where we actually flew, so we can't comment on whether there actually was wave breaking or not. We didn't get quite that high. But it looks from this like we were just approaching some really strong area of upper lift, which I tend to believe. On the way home we flew downwind. I didn't put that into the graphic, but we did actually get a fairly strong area of lift in the third harmonic back.

This is some supporting data for pretty much the same time. This is from Dong Wu at the Jet Propulsion Lab. It's some radiance data from the Aires satellite. It shows that there's quite a bit of temperature perturbation activity in the same area we were flying. This is at two and a half hectopascals and down here is at 50 hectopascals. His data cannot resolve features less than 50 kilometers wavelength, so this is not the kind of wave we flew in, but it indicates that the waves were quite strong in that area at that time. This is some temperature data from on board the sailplane. We had some high response, high quality temperature measurement instrumentation we flew with. There are a couple of interesting things about it. One is we got a pretty good lapse rate here, I think something like six degrees per kilometer. Here's the stratosphere, maybe 34,000 feet, and the data's pretty well aligned here in the troposohere. But in the stratosphere we get a great deal of temperature variation, and that's due to moving back and forth, upwind/downwind in the wave, hunting for it, trying to center the up region. It shows that there are very strong horizontal temperature variations when you have a wave penetrating the stratosphere. That's always going to happen, which could be of significance for some kinds of airplanes.

Having decided that we’d proved the concept, we started to design and build a new sailplane to get rid of the pressure suits and use a pressure cabin and special aerodynamics for very high altitudes. This shows a conventional sailplane. The blue is a conventional sailplane and vertically is just kind of an indication of aerodynamic efficiency; it’s a function of Reynolds number. At sea level you’re here. At 60,000 feet the Reynolds number drops down, and here’s 90,000 feet. It shows that aerodynamics for an ordinary sailplane really degrade performance a great deal. But if you design an airplane for 60,000 feet then you can minimize that degradation of performance.

This just shows some balloon assent rate data from Jim Rosen at the University of Wyoming, and it shows that this right here, the blue line, is a Eliassen-Palm kind of a rule. It doesn’t really apply to this because this is a big wave field with lots of harmonics as a balloon drifts downwind. But it does show that waves get higher amplitude as you go higher. The red is computed sink rate for the sailplane, so it shows there’s always a margin for climb up to 30 kilometers.

Here’s the fuselage as of about a month ago, just getting started coming out of the molds. Here’s a picture of the sailplane rendering, and that’s an emergency descent chute in case we have some big trouble at very high altitude. There’s a mother of pearl cloud that we’d like to be looking down on in a couple of years. Thank you. (applause) And if there’s any questions, and if they’re too difficult, I’ll ask Elizabeth Austin to field those for me.

Jay Fein:
Thank you very much, Einar.
We’re going to begin now and pick up on any questions that you all might have to ask of Einar. No? Let me ask if anyone in Boulder would like to comment or ask Einar any questions about his discussion on the Perlan Project.

Joach Kuettner:

Yes, I have a question. Do you know about the stratospheric glider that we got approved 30 years ago and then was cancelled in one afternoon by the Air Force? That was the pressurized cockpit, and you were the one who picked this problem up, and finally you are going to make it.

Einar Enevoldson:

I do know a little about that project. Vic Saudek was a good friend that was in the middle of that project. The cancellation was unfortunate. I think the project was premature for a couple of reasons. The technology for building a sailplane that would really fly well at that altitude was not established at that time. Since then, there's been a tremendous development in aerodynamics, aerodynamic design, and also in the carbon fiber construction that makes possible a fairly practical glider that has a good prospect of success. And then the other thing -- I don't think anybody was really aware of the significance of the polar vertex or the stratospheric polar night jet at that time, which is where the real potential exists -- not to say that it wouldn't have been possible to fly up probably 55 or even 60,000 feet in the United States on rare occasions. So I think we're in a much better place to carry on that work now than we would have been in 1955.

Joach Kuettner:

Are you already building parts of this airplane?

Einar Enevoldson:

We are building. We're building the fuselage and the pressure cabin. We think that's the technologically most challenging part right now. It's the most innovative part of the glider, the re-breathing system and the pressurization and all of that part. We have enough money to do either the wings or the fuselage. So we decided that we would spend the money that we have and build a pressure cabin and the fuselage, and hope that with that as an example of how far we've come, we can collect enough money to finish the wings now.

Joach Kuettner:

Yes. Can you say anything about the wings? Do they have fantastic aspect ratio or better aerodynamics?

Einar Enevoldson:
(laughter) Well, they do. You certainly could not have built wings like this in 1955. It has, by modern standards, a fairly modest aspect ratio of 26, which would have been unthinkable in ’55, but I’ve just been looking at some design studies and it looks like the higher you want to go the lower the aspect ratio should get, and...

Joach Kuettner:
The higher you go the lower what should get?

Einar Enevoldson:
The aspect ratio should be lower to optimize the airplane for a very high altitude, but our assumption is that our most difficult part of the flight is in the vicinity of 50,000 to 60,000 feet where most often we’re going to have the weakest wave, so that’s the design point, the optimization for the glider. If we wanted to design it for absolute maximum altitude, we’d probably use a lower aspect ratio on the order of 20, but we wouldn’t do quite as well going through the 60,000 foot region.

Joach Kuettner:
Thank you.

Jay Fein:
Thank you very much, Einar. OK. Thank you again, and I apologize for the break in your talk.

Ron Smith:
Jay, thanks very much. Joach, it’s good to see you. I’m going to try to take one bit of Joach’s career and put it in the context of aviation technology over the last century. It’s kind of a tall order, but I’ve kept in a few key points. I’ve had to drop out a lot of things, but let’s get

started with that. I don’t think it’s hard to look at a mountain wave without getting a feeling of mystery and wonderment. They’re just such beautiful shapes, the way they move, the way they extend vertically up into the atmosphere, the way they change from day to day. We know that there are mountain waves – we wouldn’t have to be in an aircraft to know that – but we’re reminded when we see such beautiful diagrams of mountain wave clouds. Of course, we can see them from satellites, as well. That gives us a better view, in a way, because we can see how they’re distributed horizontally and how they’re generated by certain particular terrain features in the landscape. They have important impacts on the atmosphere: they transport momentum to higher levels, where they can control upper level jet streams and currents that produce clear turbulence. The turbulence, in turn, mixes the upper layers of the atmosphere. In the lower troposphere they can generate severe down slope windstorms. Going back aloft, again, the wave clouds can be the sites of important chemical reactions in the stratosphere. Back on the human reaction to these waves, I think wave motion, in general, interests us. I remember as a child getting back late from school every time there was a rain storm because I would be standing in a puddle on the way back watching waves being generated as the water ran down the gutters in the street. I think this gentleman on the surfboard has that same feeling.

Now, I don’t know honestly when it was that pilots first began to wonder and wish about getting their aircraft into a mountain wave, but I imagine it came quite early. How early? Perhaps I’m overestimating that, but I bet it wasn’t much after this when pilots began to think how wonderful it would be to get an aircraft up into a mountain wave. That’s certainly an emotion that, I think, has been in the back of Joach’s mind all these years, and some others. I share it. So today I wanted to pick out just five technical innovations - one could choose others but I like these particular five - that have really pushed the observations of mountain waves forward. Joach has been involved in one way or another in all of these. I’m not claiming that he invented these things, but he certainly got the ball rolling and has been pushing that ball down the field, encouraging people to invent and to create and to test these new innovations throughout his career. I’m going to talk about the barograph and variometer, isentropic analysis, gust probe in the inertial platform, airborne lidar, and GPS altituding pressure. I'll go quickly through these; there isn't too much time.

But first, to put these in a chronological context, let's see: on the top line - that's the Kuettner line - you can see some of the projects that he was involved in. Hans spoke about the work in Europe: the moazagotl, the foehn, the rotors. He spent time in the Zugspitze, got involved in the Sierra Wave Project, worked on Mount Washington. I've skipped in that diagram, left out some work he did in Boulder. I first met him in ALPEX, as Jay indicated. After that, Joach published some work on convection waves. Then I worked with him again on MAP, and then along came the rotors, and T-REX. Vanda's going to speak about that. Now, on the bottom line you get the airborne technology. It wasn't long after the Wright Brothers that we got into this era of glider development. Along with that came a kind of competitive and exploration aspect of gliders - trying to get higher, trying to fly further, trying to set records. Some of this was in Germany, for good reasons. The Treaty of Versailles stripped Germany of her ability to develop powered aircraft for a number of years, but that human instinct of wanting to advance, to fly, to advance aeronautical technology then had to be channeled into unpowered flight. It's not surprising that Joach got caught up in that. It played an important role in mountain wave research. Then came isentropic, the gust probe, the LIDAR, and the GPS. So there's the timeline for the items that I'll be talking about.

Barographs and variometers now seem like primitive instruments to us. We just have to measure the pressure. We can use a diaphragm device to do that. If there's no leak and it's well calibrated, it gives you pressure which can be converted to altitude in a typical aviation altimeter. If you put a slow leak in it, you can turn that into an approximation of vertical speed of the aircraft, at least, and maybe an approximation to the vertical speed of the air, as well. Look back at some of Kuettner's early research publications; here's a diagram from a glider flight. Basically the solid line there is altitude - it's really pressure, but pressure converted to altitude - and as the glider goes up and down, you can imagine that there are vertical currents, up currents and down currents, at the locations indicated in that diagram. So that's our first way of measuring vertical velocities in mountain waves. Here's another example. Again, the upper diagram shows pressure plotted as a function of time, and the lower diagram shows an estimate of understanding how the aircraft was actually caught up in a rotor in this situation. So the simple measurement of pressure had a very key role to play in the discovery and the study of mountain waves. When we got to the Sierra Wave Project a few years later, we began to use aircraft in that project but gliders were still an important part of it. In both cases pressure altimetry was the main tool.

The next one, of course, is what's today called isentropic analysis. It's simply recognizing that the potential temperature is a conserve tracer as air moves up and down in the atmosphere adiabatically. If we can measure by flying through these mountain wave systems and measuring temperature and pressure, combining them to form potential temperature, and then contouring that quantity, we immediately have a nice kind of streamline map. Now, we have to make some assumptions about steady state and so on; I won't belabor that. These are wonderful diagrams because they give you an idea of how the air is moving up and down, and really gets us a big step forward in our understanding of mountain waves. This is from a paper, Kuettner and Lilly, 1968, so you can fit that onto the timeline. And then, of course, this famous diagram, the famous January Boulder windstorm, is using that same technique. It's simply isentropic analysis. Imagine that you're seeing their evidence that the air is descending by many kilometers and then quickly ascending again, as deduced simply from profiling potential temperatures. It's a wonderful tool, and of course, we still use it today. But then, a real giant step forward is the gust probe and the inertial platform. This really has set the field on its ear and started us off in a new direction. Whether you do it with a vane device to measure the fluctuations in how the air is approaching the aircraft with a mechanical vane or whether you do it with a differential pressure device, you need to understand the air motion relative to the aircraft. Then, of course, you need to understand the attitude and the motion of the aircraft itself. That requires an inertia platform, at first done with a mechanical gyroscope system. Later on the technology advanced to other kinds of accelerometers and laser ring accelerometers and so on. But if you have both those things in place, the ability to measure the air relative to the aircraft and the ability to know exactly what the aircraft is doing, then you can begin to measure the wind speeds directly. That was a big step forward.

For example, the left-hand diagram shows the aircraft. You have to know its angle, how it's accelerating, and then measuring the air speed relative to that allows you to get all three components of the perturbation wind, u, v, and w, and one of the first applications for that, of course, is to compute the wave momentum flux. The importance of this quantity was put forward in a classic paper by Palm and Eliassen some years before. This was one of the first attempts to measure it using a gust probe system.

As Jay indicated, I met Joach for the first time in ALPEX. This was quite a marvelous experiment to me. Somehow Joach's experience in working, kind of connecting U.S. science with European science was a key for that project. It gave me a look at how large projects work, and yet why one needs to be basically grounded in the science. It's not enough to be an administrator; one has to be basically grounded in the science and the technology, as well as being a sharp and acute administrator. We didn't do a lot of mountain wave work over the Alps in ALPEX, but this is one of the things that Joach gave me particular assistance with. I was trying to find a way to do something new in that project and thought about doing it over the Dinaric Alps in the East, something we hadn't really said much about in the run-up to ALPEX. But Joach took me aside and gave me some pointers about which aircraft to use and how such flights could be done. I tried to put that together into a project, and it ended up being a rather successful first observations of how the Bora winds form along the Adriatic coast. We used the Electra and the P3, among others, for that. And we used, of course - you see in the upper right - isentropic analysis, but we also used the gust probe in the lower left, or the turbulent profiles, which came from the gust world. So we're accumulating these technologies. When you invent something good you don't drop it; you keep it and then you add to it as the years go by.

Then along came MAP 17 years later, back in the Alps. We did some better mountain wave work this time. I'll show you a diagram from the Mount Blanc flight, which is number four on that diagram, and there's a new technology coming in at that point. On the right you see a cross-section; the X axis is horizontal distance, the vertical axis is altitude. This is a cross-section across Mont Blanc, the highest mountain in Europe, and you see the peak of it there near the left side of the diagram. The airflow is from left to right, and there are two types of things in that diagram. The DLR Falcon is flying right about up here, just at the top of the diagram, with a down looking LIDAR, a back scatter LIDAR, that is able to penetrate cloud layers and give you information from the first layer that it sees, the next layer that it sees, and even the layer beneath that. By using a ranging device, of course, it's able to detect vertical displacements of this, and then in the solid lines you find the vertical displacements of air that we have deduced from the gust probe. So again, we are compounding these inventions and using them together, and we see, for example, how the cirrus layer is being moved up and down by the waves. By the way, here's a picture taken from a pilot flying at lower altitudes at that time, and it shows you the three types of clouds: the cirrus aloft, the lenticular clouds in the middle - that's this one here - and then some cumulus clouds below that which are also being distorted by the mountain waves. So you can see how the LIDAR is able to pick up the displacement and the occurrence of these clouds and how that agrees with the measurements taken from the gust probe. We're learning more and more about waves as these technologies add together.

Finally - and this brings us up to the most recent project that Joach was involved in, this is the T-REX project - now we have GPS. What does GPS add to our toolkit? Well, remember in the first part of the talk that pressure historically has been used to determine the altitude of the aircraft, and so we couldn't use it to determine pressure that was dynamically acting in the atmosphere. We'd already used it up. We're using it for altitude. But now that we have GPS to give us aircraft altitude, we can measure the pressure that is involved in these atmospheric dynamical motions. Of course the most remarkable thing this allows is that now we can measure energy flux. Gravity waves move from place to place in the atmosphere by their pressure velocity correlations. Now we can measure energy flux. In the lower diagram you'll find a comparison between energy flux and momentum flux, checking on the Eliassen-Palm result relating those two important quantities in mountain wave measurements.

That is the fifth and the final of my technologies. I'll just summarize by saying that Joach's career spans this whole development of the aircraft itself as well as of these technologies that are used to measure mountain waves, and his enthusiasm, boldness, and leadership has been a constant progressive force, pushing this field forward and setting an example for future scientists. Thanks, Joach, and thanks for listening. (applause)

Vanda Grubisic:
Thank you, Jay, for this introduction. Hello, Joach. And if I may correct you, it is 1365 for the University of Vienna. (laughter) The title of my talk, as you can see, is Rotor Puzzle. The words "mystery" and "wonderment" have already been mentioned today. It is so fitting that I start with a quote from Albert Einstein, and I'll read it: "The most beautiful thing we can experience is the mysterious. It is the source of all true art and science. He to whom this emotion is a stranger who can no longer pause to wonder and stand wrapped in awe is as good as that. His eyes are closed." You might ask, what is that aside from mountain waves that we should pause to wonder and stand wrapped in awe, and this is rotors, something that forms a continuous thread throughout Joach's career. Phenomenon - a turbulent companion to these smooth and beautiful mountain waves, something that every glider pilot knows about well because they have to fly through this on their way to smooth waves and the smooth aerial elevator that these waves provide, as we have heard from Einar. Here in the diagram you can see where that rotor is down near the mountain crest. It's indicated in this diagram that actually goes back to Joach as a horizontal vortex. There is little indication that there is anything inside that, but there is quite a bit of turbulence as you can see described in the statement. It's a flight report from the Chief Pilot for the Sierra Wave Project, John Robinson, stating "+5s and -4 Gs very rapidly are happening in a rapid sequence, and this turbulence was far in excess of anything I had ever found in thunderstorms, which I had

been deliberately soaring in for many years.” You can understand this wonderment on the part of Joach, a young glider pilot and a scientist, having to fly through this terrible turbulence on the way to waves. And he was acting both - he was thinking both as a pilot and a scientist. There’s this challenging problem: it’s small scale, it’s very intermittent, it’s very dynamic, but he was also thinking, as a pilot, about the immense societal benefit and the aviation safety that would be brought if we understood what it was and if we had a capability to predict it.

As you heard today, this is where it all started in his research in the lee of the Riesengebirge in Germany. Here’s a diagram from his Ph.D. thesis, and the lower turbulence zone is indicated here; there is a degree of coherence in that lower turbulence zone that reflects, mirrors the waves aloft. There is indication even of the reverse flow of the ground, so if one thinks of a horizontal vortex paralleling the mountain range, the reverse flow should be there. He is a keen observer, after all, so he linked ground and aerial observations in the lee of the Riesengebirge. There’s an indication down here in this diagram with lee waves, or there’s a regime with lee waves with rotors indicated there; ground observations come from wind observations at Sinecope, which is the mountain peak. That is the dashed line here, which shows wind speed as a function of time. There’s a note here that Sinecope’s direction is constant south-southwest, but the station on the lee side shows the change of wind direction, a sudden change of wind direction from southwest to east back to southwest back to east, and so on. So there is some indication, some support for this flow reversal and the horizontal vortex perhaps being there.

We leap forward and change the continents now. We find Joach on the North American land in the U.S. He is a contract monitor at the newly formed Cambridge Research Center, U.S. Air Force Cambridge Research Center, but he is also a scientist. He is expected to develop his scientific portfolio, and he is a glider pilot wishing to fly again. He soon receives a proposal from the Southern California Soaring Association that was done with UCLA. That proposal is to study the strange lift on the lee side of the mountains, where common sense tells you that there should be a down draft, but there is this strange lift. The German pilots have been documenting it. The Southern California Soaring Association pilots also flew in that in Owens Valley. Now they are proposing a scientific project. You can imagine the inner joy of a program contract monitor seeing such a proposal, and he says, “I have to look into this before I make a decision.” And so he looked into this, (laughter) and yet the program (inaudible). It resulted in a funded program in this beautiful place called High Sierra in Owens Valley, a tall mountain range called the Sierra Nevadas, another one downwind, a deep and wide valley, deeper and wider than anything Joach had seen so far coming from Europe and from the Alps where the valleys are narrow and steep. And he loved it.

The program had a strong observational component. They used two gliders, but you see here this one was used in the first phase, this one was used in the second phase. I love the suit, but you must admit the scarf is just a nice touch. (laughter) And the theoretical program was strong. It was based at UCLA. It was led by Holmboe and lots and lots of other Scandinavians names you see. Jacob Bjerknes was there, and then a stream of graduate students, and others, and a number of short- and long-term visitors. There was a scientific component in the U.S.A.F. Cambridge Research Center, and that one was by Joach himself. Here you see the giant - not really literally in terms of height, I think Scandinavia’s there - Kenney, Bjerknes, Kuettner, Holmboe, in Owens Valley. You see the Sierras in the background. What did they find? It was an amazing program, ambitious, bold. They used gliders. They tracked them from the ground. It took them years to get the quality control data set, nothing compared to our three months these days. It took five years. They found two types of waves, and then there are two types of rotors. Lee waves produce one type, well organized, nice, rough, but that one was actually better behaved than the other. This is the beast, looking like a hydraulic jump. We’ve seen this photo earlier today. There’s tremendous pickup of dust from the ground. There’s a cloud on the lee side. As a matter of fact, they flew through at least one of these during the Sierra Wave Project.

The nice theoretical component comes from Joach. It is an application of a hydraulic model to try to explain the down slope windstorm and the hydraulic jump type rotor, applying hydraulic theory, (inaudible) the ground to explain the jump that’s higher than the upstream height of the layer that’s approaching the mountain. But then there’s a gap of several years, not only several years but a few decades. This quote from Joach’s paper in 1963, which has an interesting title, *Evolution and Mutation in Atmospheric Science* - and I highly recommend you read it - as the base of research is quickening further. "Whole scientific fields are born, sold, and put aside within a lifetime. The problem of versatility inescapably faces every one of us, and peculiarly enough, it does so in a world of increasing specialization." He certainly was talking about himself in part here, and that versatility is really his willingness, readiness to accept new challenges. That new challenge was a U.S. manned space program. That took him away from rotor research, from wave research for quite a few decades. But he made his way back, and this is in preparation for the next field adventure: Joach Kuettner becomes a numerical modeler. If you are going to venture into new fields, you better do that in collaboration with the people you trust and you know they think the same way you do. Here you have two gliders doing a numerical modeling study on rotors, trying to really prove that there are two different types of rotors and trying to understand the reason behind it. It goes back, again, to the Sierra Wave Project observations of the particular atmospheric structure. You see here potential temperature profiles, stable layer inversions, stable layer strongly stratified on the stratosphere here, and the wind profile is a strong positive wind shear. But then there’s this detail within the inversion, two different types of wind profiles, one with positive shear and one with negative shear, and the positive shear one produces this flow realization downwind of an isolated ridge, whereas this one with a negative shear produces something rather less orderly, far more intermittent and far more dangerous looking. There is a suggestion in that paper that this is that type of flow realization and this is the other part of flow realization.

Along the way he was motivating quite a number of people, suggesting to them to look into this problem. Quite a number of us, including myself, saw Joach as increasingly becoming a mentor, what he was during the whole of his lifetime but in preparation for this next field adventure, he really, really put us forward, the group of us, and there it is, theoretics experimental design. We again have multiple aircraft. We did - you heard bits and pieces of isentropic analysis, of waves, and then we had this wonderful little aircraft that we actually flew through rotors, and we had the ambitious ground and base component, and Joach was there with us. He was admiring this new technology, remote sensors rather than trying to fly directly, which we also did using remote sensors and trying to see what's inside a rotor. And he also flew with us actively. This is courtesy of Yoker Communications. I am bidding him farewell on a research flight. This is toward the end of T-REX. It's IOP15. It's a documented mission, and there he is making steps into a King Air. If you've ever been in the King Air, you know that there's one more difficult step to get into the co-pilot seat, and he did it. And then we had, of course, as many landings as takeoffs, so here he comes. (video plays) And the scientist mission report followed, and I can also tell you that not all mission scientist reports are such nice reading. (laughter)

If we look into the rotor's internal structure, which we can now do using these remote sensors, we indeed see a rich structure. This is one of our flights. You see cross sections in the isentropic analysis from the aircraft data. The aircraft has a remote sensor, which is the dual Doppler cloud radar. We can look down into the structure with the back scatter radar. This is the dual Doppler analysis of the flow field through the wave and then through the rotor. Note the richness of this small scale structure and the intense vorticity, which are responsible for those plus and minus Gs that one experiences flying through this region. I think we are close to offering, and we are already publishing it, an insight into this internal rotor structure. We have a better understanding that these are indeed associated with wave induced boundary related separations which lead to the instability of that separated boundary layer sheer line. Here you see the vorticity - this is horizontal vorticity in color - and you see that rich structure inside the rotor. The rotor would be here. Now you see how difficult and complicated those earlier simulations were. I'll stop here. Joach, happy hundredth birthday. (applause)

Jay Fein:

Any questions from this audience, or comments? Yes. Why don't you come up here?

Audience Member:
Vanda, thank you very much for this presentation. A curious question I have: the very early schematic diagrams show or imply that it's a steady rotor thing which probably can't be true while your surface observation from the (inaudible) place shows the intermittency. What would be your perhaps not final but recent comment now after T-REX? What is it really? Do you sometimes have a full-fledged vortex? Is it a long line or is it just an imagination, an over-imagination which we owe to Joachim to start with? (laughter)

Vanda Grubisic:
I wouldn't call it imagination. I would call it the ability to synthesize and to simplify. If one looks at any given moment, the structure is extremely turbulent, and these flow reversals at the ground are indeed intermittent. The conceptual model with the horizontal vortices is a still useful one. If one thinks in a time average sense, averaging over a certain time period, there is some indication that there is a time averaged larger scale vortex. So in a time average sense that conceptual model still applies.

Jay Fein:
Thank you, Vanda. Any other comments or questions? May I ask the same of participants in Boulder? Any comments or questions, please?

Joach Kuettner:
I have a question for Ron Smith.

Ron Smith:
Joach, I'm here.

Joach Kuettner:

Yes. I want to ask you a question that I may have asked you a long time ago, namely do you consider the rotor problem solved? That's my first question. And I can tell you what I think about it later. (laughter)

Ron Smith:
(laughter) I think he's... That's a setup! So I guess I'll try that one! Is the rotor problem solved? I don't think science works quite in that way. I think the most successful scientists are those that can ask the right question, a question that is important and that can be answered, but then when that cycle is finished, the field may lie dormant for a year or two. But then new questions arise. I think that certain things have been well established - a relationship between gravity waves and the existence of the rotor - but I'm sure that if we asked that question in five years, there will probably be new questions that come forward. So I'm afraid I'm going to hedge my bets on that one. (laughter) Was there a second question?

Jim Moore:
Doctor, did you have another question?

Joach Kuettner:
I had another question but I have forgotten it. (laughter)

Ron Smith:
But you had an answer!

Joach Kuettner:
Not yet!

Jay Fein:
Joach, we are a very flexible crowd here. When either that second question or answer comes back, just interrupt us. We'll bring Ron back.

Renate Brummer:
Good afternoon, everybody. I would like to honestly share with you that I feel very honored to have been asked to be a speaker here at Joachim

Kuettner’s special symposium. I’m enjoying every minute of being here. I think we will all remember a lot of these talks a long time after this AMS conference, even as much as we forget many others too easily. (laughter) I brought two cups with me; one has a lot of water in it because it is quite warm up here, and the other one is to cover the red blinking light, (laughter) because when you talk about space research and spacecraft, red blinking lights mean a lot of bad things are happening. I couldn’t find a green cup, but it’s as green as possible, so I’ll leave it here! (laughter)

Jay Fein:
I must say, Renate and I negotiated over lunch, and she will have extra time. (laughter)

Renate Brummer:
Thank you. I would like to tell you about Joachim Kuettner’s involvement in the beginning of the United States Manned Space Program during the Mercury and Apollo program time. Have you noticed, those are the years which are all blackened out on the wonderful timelines shown by a lot of the scientists today. There was always this gap, and fellow scientists said, “We don’t really quite know where Joachim went, but he didn’t help us with any of our mountain wave research anymore.” (laughter) We have already heard that in the late ‘30s, Joachim gave a most amazing first comprehensive explanation of mountain waves. Everything I’ve seen today fits really well into my talk. This is just my interpretation, but I think Joach always likes to work on a platform, which is as high up as possible, altitude-wise. My next slide, which you saw in Rick Anthes’ slideshow, is from 1945 with Joach in the position as Chief of the Zugspitze mountain observatory in the Alps. That’s as high as you can get. In Germany the Zugspitz is the tallest mountain we have in the very south end of the country in the Alps. Here’s a beautiful picture with a view to the south. When he came to the United States around 1949, he started working as a scientist at the Air Force Cambridge Research Center. He became the Scientific Field Director of the Sierra Wave Project, as we have heard now in many talks, and sure enough, that allowed him to get into gliders, flying very, very high.

Talking about high, Joach set a new world soaring altitude record at that time of 13,015 meters, which translates to 43,000 feet, over Bishop, California in May 1955. Here on the left you see he got a certificate from the German glider club he belonged to certifying the enormous height he had reached. Just to get a little bit of perspective, when you fly on a commercial airliner, if you fly really high, you're at a flight level of 36,000 feet. Getting up to 43,000 feet in a glider, with no rocket or jet engines, is an enormous achievement. And from everything I've heard, this record actually was only broken 52 years later in 2007 by Einar and Steve Fossett. I guess that's correct? Right. Thirteen thousand meters is not quite at space level. A common understanding is that space starts at 100 kilometers, but we're getting closer. The launch of Sputnik by the Soviet Union on the 4th of October, 1957 really defined the Space Age. This amazing little satellite totally surprised especially the Western world. It was tiny at only 58 centimeters in diameter. Have you seen a spacecraft of that size any time in the last decades? It weighed just 84 kilograms, with a real scientific payload: two temperature sensors, an inside and outside one, and a radio with two frequencies. It lived for six months. If you had a special receiver you could hear this. (recording plays) Some of you may remember this. It was this very beep tone which woke up a lot of the Western world and really triggered an enormous space exploration race. It also especially triggered a lot of funding so the U.S. could catch up with this development.

If we talk about space development and rocket development, the name Wernher von Braun is a very important one. He was one of the most influential rocket developers and champions of space exploration during the period between the '30s and the '70s. von Braun became the first Director of NASA's Marshall Space Flight Center. He was the chief and architect of the Saturn V launch rig - I'll talk about that later. In this wonderful photograph, there's an autograph dedication for Joach, which says, "To Joachim Kuettner, with appreciation for his pioneering work in bringing the human formula into our first manned rocket flights. Cordially, Wernher von Braun." But what was the link between Wernher von Braun and Joach? Well, they were both outstandingly good pilots - not only of gliders but many other aircraft as well. In Bob Ward's book, *Dr. Space: The Life of Wernher von Braun*, he described a very important event which links Wernher von Braun and Joach. In the aftermath of the Sputnik launch, in November ’57, von Braun telephoned an old colleague in Boston, Joach Kuettner. von Braun was not working for the space team at that time but was at the Army Ballistic Missile Agency. He asked Joach, “Would you want to head up a project to put the first man in space?” “Of course,” Kuettner answered, “but I think I don’t know anything about it.” “Neither does anybody else,” replied von Braun. Recalled Kuettner, “That was all, and I was off for Huntsville.” (laughter)

It was a year later that the National Aeronautics and Space Administration, NASA, was actually established. The mission was to perform civilian research related to space flight and aeronautics. Here’s a picture of President Eisenhower when he commissioned Keith Glennan, here to the right, as the first Administrator for NASA, and Dr. Hugh Dryden as Deputy Administrator. Just two months later, Glennan announced America’s first man in space project, which later on was just called Mercury. It should have been called the Mercury Redstone Program. This big Redstone rocket with a spacecraft on top had the goal of putting humans in orbit around the Earth and bringing them back safely. Joach was nominated to be the Director of the Mercury Redstone Project and the Chairman of Crew Safety, an enormously important position at that time.

If you want to run a space program, you have to have astronauts to fly on the spacecraft. The first seven American astronauts were selected in April 1959. They were called the Mercury Seven. Here’s a wonderful picture of those guys. From left to right you see Gordon Cooper, Wally Schirra, Alan Shepard, Gus Grissom, John Glenn, Deke Slayton, and Scott Carpenter. The Mercury spacecraft was truly small; it was more like a little metal can. Just one crew member fit in it. This manned spacecraft’s height was 3.5 meters, the diameter was 1.89 meters, and it weighed just 1,900 kilograms, which is less than 4,000 pounds. It had a tiny little exit and entrance hatch which the astronauts actually had a lot of trouble getting in and out of. We don’t have a photo of the very, very high-tech heat shield, but it was an extremely important feature to allow the spacecraft to cope with the re-entry temperatures, which get up to 2,700 degrees Celsius. And they made it. The first manned Mercury flight was conducted by Alan Shepard on the 5th of May, 1961. Launched at Cape Canaveral, it was a sub-orbital parabolic flight which then splash landed in the Atlantic. It reached 116 miles in height and a speed of a little bit more than 5,000 miles per hour and lasted all of 15 minutes. This was a huge success. However, in spite of that, three weeks later the Americans were very depressed because the Soviet Union launched their first man into space. Yuri Gagarin actually flew once around the Earth's orbit. Alan Shepard later commanded the Apollo 14 mission and was one of the people who walked on the moon. I'm showing quite a few of these autographed pictures because I think personal autographs say a lot about how people relate with each other. Here is Alan Shepard's dedication which reads, "To Joach Kuettner, with warmest personal regards and thanks for a perfect Redstone," - that's a rocket - "Alan Shepard."

The second flight occurred shortly thereafter. Astronaut Gus Grissom piloted the Mercury Liberty Bell 7 in July '67. The astronauts were permitted to give the Mercury spacecraft personal names, which was a nice thing; Grissom named his the Liberty Bell 7. This was the second and final parabolic-only or sub-orbital flight. Gus Grissom later also flew on Gemini – I'll talk about that later - and unluckily, he was also one of the three astronauts on the Apollo 1 mission which had a catastrophic fire during a launch exercise. On this autographed picture, Grissom's dedication reads, "Thanks, Joach, for making this a wonderful day. Gus Grissom, Liberty Bell 7." Gus and Joach worked very closely together on a lot of crew safety and other issues. The third Mercury flight was a manned spacecraft circling in Earth's orbit. The flight duration of John Glenn's flight on February '62 was five hours. It made three Earth's orbits and soared to a height of 98 miles. In this case the spacecraft reached 15,000 miles per hour. John Glenn's dedication to Joach says, "Best regards to Joach, Jack, in my sincere thanks for all the help, John B. Glenn, Jr." Here's a picture of Joach in the Space Flight Control Center just before a manned Mercury Redstone launch. You can see the tension. Launches obviously have a very tense atmosphere because they were and still are a really dangerous part of space missions. I think it's a great picture and speaks a lot to what's happening there.

This is a schematic of the landing site. Here is Cape Canaveral in Florida, from where all the launches occurred. Here are the landing sites in the ocean of the first parabolic flights. Alan Shepard's is the Freedom 7. Gus Grissom's Liberty Bell 7 landed right next to it. However, the latter was not without problems. The exit hatch actually blew off accidentally and the spacecraft filled with water very quickly. The rescue boats weren't there yet. Gus nearly drowned. Luckily they reached him just in time. John Glenn's landing site is here where it says Friendship 7. A follow-up flight by Scott Carpenter was off target by 400 kilometers. He landed here where it says Aurora 7. All the rescue ships were roughly in this area and looked for him forever. There were a lot of problems we can't go into here. It was anything but smooth, but it still worked amazingly well. All the other red dots are Gemini flights; I'll talk about that in a minute.

The last of the Mercury flights - I'll skip a few - was with Gordon Cooper, who flew in May, 1963. He flew the longest space flight of the Mercury program: a day and ten hours long. He was the first American to actually sleep in orbit and was the last American to launch alone into Earth's orbit. He had to launch alone because the Mercury spacecraft could only fit one crew member in it. From several conversations with Joach, I learned that Gordon Cooper and Gus Grissom were the astronauts who worked most closely with him. Cooper's dedication says, "All best regards to my good friend Joach, Gordon Cooper."

I guess most of you flew here, maybe on a Delta or United flight, cramped in your economy seat, complaining that you didn't have enough space. Well, this is the space environment of the Mercury crew in a Mercury spacecraft. Here's a chair to sit in. Here's where the legs go. Here's an armrest, there's a joystick, there's a dashboard. That's all they had. If you can imagine Gordon Cooper sitting in here for one and a half days, putting up with these kinds of conditions while doing everything he did, you have to agree that this truly was an amazing achievement.

Here's a photo from *Life Magazine*, published in 1959, with Joach and astronaut Gordon Cooper inspecting the Mercury Redstone rocket. This brings me to another area: On May 25, 1961, President John F. Kennedy made a speech before the joint session of Congress announcing the United States' decision to go to the moon within the decade. This was an amazing announcement because it happened literally 20 days after Alan Shepard completed his 115 minute parabolic flight and landed in the Atlantic Ocean. At that time, the United States committed to flying human astronauts to the moon, land them there, and bring them back safely. This presented enormous technical challenges. In order to go from a relatively "simple" Mercury program to landing on the moon, a lot of additional technological tasks had to be mastered. Much larger spacecrafts, with enough room for two or three astronauts were needed. That meant much heavier spacecrafts, thus much heavier rockets. Higher escape speeds were needed for these spacecraft, up to 25,000 miles per hour, not just 5,000. Astronauts had to learn how to conduct space walks. They had to be able to get out of their pressurized capsule, into space, through some type of airlock, and get back in. They needed special spacesuits to survive a space walk like this. Additionally, there was the huge technological challenge of being able to rendezvous between spacecraft, which required being able to undock and then dock back together again. The spacecraft circled the moon while the lunar module separated, descended to the moon, blasted off, and then re-docked with the orbiting spacecraft. The Gemini program solved all of these challenges very successfully. In June '65, astronaut Ed White in Gemini 4 was the first American who made a very successful space walk. In December '65, the rendezvous between Gemini 6 and 7 occurred and also worked extremely well.

We were ready for the Apollo program: to land humans on the moon and bring them back safely. While Joach was not involved in the Gemini program at all, he played a major role in the Apollo program. He became the Systems Integration Manager for the Saturn V on the Apollo spacecraft. Saturn V, the rocket here in this picture, does not look very different from the Redstone rocket we saw before. But here is a photo that shows the scale of these rockets. This is in a Redstone rocket; there's a Mercury spacecraft on top, and then on the right you have a Saturn V in scale with an Apollo spacecraft on top. The difference in scale is gigantic. I found this wonderful statement on Gizmodo.com which I want to read to you: "If you talk about the moon landing, some people remember Armstrong and Aldrin walking on the moon. I choose to remember the rockets that enabled it all: the Saturn V, a pretty shocking mechanical masterpiece all by itself. Nearly everything about it is monumental in scale and historic in importance." I think this is a wonderful statement. Here are some facts: Saturn V was the largest operational launch vehicle ever produced. At 364 feet high it was roughly as tall as a 36 story building. Its launch weight was 6.7 million pounds - this is rocket and spacecraft - and it could actually lift orbital payloads of up to 260,000 pounds. The Saturn V was masterminded by the rocket team at the Marshall Space Flight Center under the supervision of Wernher von Braun. That's the very team Joach was a part of. In this photo, the rocket is lying down at the Houston Space Center. To give you an idea of the Saturn V's scale, look at the size difference between the people here and the back side of stage one of this rocket.

In December, 1968, Apollo 8 launched and took the first astronaut around the moon. Crew members were Frank Borman to the right, and then Anders and Lovell. Borman and Joach were co-chairs of the Apollo Crew Safety Panel, and they also worked very, very closely together. Borman's dedication demonstrates this. He says, "To Joachim, with appreciation from a friend and former partner, Frank Borman."

Apollo 11 landed on the moon on the 20th of July '69 with Neil Armstrong and Buzz Aldrin in the lunar model and Michael Collins orbiting around the moon. I think this can still be called the biggest technological achievement of the 20th century. This is a beautiful picture of Aldrin coming down the ladder, taken by his colleague Armstrong. Truly, they left their footprint on the moon. As you know, there aren't any winds up there. Nothing is going to blow those footprints away. Many of us remember this... (recording plays of Neil Armstrong saying "That's one small step for man, one giant leap for mankind.") Here we've got this unbelievable picture of the lunar model coming back to dock with the command module around the moon. The sun is not rising, the moon is not rising, but Earth is rising in the background.
Apollo 11 had state-of-the-art technical equipment: We are so spoiled now when it comes to computers. Forty years ago, computers were very, very slow.

Aldrin actually had a slide ruler with him which he used to quickly make many calculations. There was no way to do that on the computers of that time. On the left lower side, you see a lunar model computer printout. Some of the most beautiful pictures of Earth were taken by the Apollo astronauts as they came home. They had pretty high resolution cameras and took great photos.

Joach, having retired in 1965, was no longer with NASA when the moon landing happened. In a recent personal conversation, he told me that at that time, the entire crew working on the Apollo program numbered 400,000 people, which is just gigantic. I guess when you're a high director and manager like he was, there is a lot of administrative work to do, like many of us know. Yes, Rick! (laughter) So I think Joach really needed to get back to atmospheric science. However, he still accompanied Armstrong on a tour of Europe after Armstrong's Apollo 11 flight. Joach's very good friend, Hanna Reitsch, shown here, accompanied them on that tour. Joach told me that Hanne was an amazing person in her own right: she was the first woman to fly a helicopter, a rocket plane, and jet fighters.

After the Apollo program, we went back to "just orbiting Earth," but we started doing a lot of science in space, which I find is really a wonderful aspect of man's space flight. Here's a picture of the first space shuttle launch of Columbia in April, 1981. This was totally new technology, including a reusable spacecraft, solid rocket boosters, which we had never had before, as well as the fluid propellant rocket. Luckily, the whole space race ended quite a while ago. Now, we have Russians and Americans and many other nationals in the international space station. Here it's actually in a view over the Mediterranean Sea. This is the southern part of the Italian boot. To the very left here on this picture is North. Here you see Greece.

In summary to date, there have been nearly 300 manned space flights that reached 100 kilometers or more in altitude with a total of around 1,000 astronauts and cosmonauts who have actually been in space. This picture came from UCAR.

Thank you so much. I leave you with this most wonderful statement by Joach: "If you can preserve these two wonderful afflictions, curiosity and the joy of adventure, through your life, you will never be able to stop exploring the atmosphere." I thank you again for your attention. (applause)

Jay Fein:
Renate, thank you very, very much. You'll be happy to know you're exactly on time. I think it is 3:00 PM. We have a coffee break scheduled, but before we take that may I ask our audience here if there are any comments or questions? That was a fascinating story, thank you.

Jay Fein:
I have a feeling Joach wants to ask a question from Boulder. If so, please.

Jim Moore:
Yeah, hi, Jay. This is Jim Moore. I have a question for Joach. I'm going to ask him since I'm sitting right here next to him. I want to know the difference between working with astronauts, who must have been characters themselves, and working with the characters in the atmospheric sciences, the gentlemen and women sitting in your audience who have spoken about you, as well as the ones here in Colorado. How are their personalities the same or different, the astronauts and the scientists, on all these projects we've worked on?

Joach Kuettner:
Yes, that is a good question, and I must say that at least in my experience the astronauts were just like any friend you have - very good relations, completely open. I don't think I had the experience of anybody being different than that, and many of them that I know were kind and understanding people, a little different from what you may read in *Life Magazine*. The press wasn't around them. They were just like you and me. Thank you.

Jay Fein:

May I ask, Joach, are you being very diplomatic or do you not want to say anything about atmospheric scientists? (laughter) What's your other question? Renata would like to say something, please.

Renata Brummer:
Just to complete my talk, I would like to tell you that you have heard I met Joach during the ALPEX years. He always gave everybody such wonderful atmospheric science advice and other science advice, but there's a whole different picture to him, too. Obviously, he knows a huge amount about manned space flight. He strongly encouraged me to apply for the German astronaut job. You could always come to his office and ask him about politics, about history, about music. He would answer all of these questions. He loved to discuss it with you. He's just a wonderful person to talk to. There's a huge spectrum, which goes far beyond rocket science and mountain waves, and I think that's what so special about him. He has a wonderful heart. Thank you very much. (applause)

Jay Fein:
Thank you, Renata. Any other comments? Yes, there is. Brad. (laughter)

Brad Smull:
This is Brad Smull here in Atlanta. This is more of a brief statement than a question, although if Joach has reactions I'd be glad to hear them. Obviously, from those who've spoken here today, it's clear that Joach has left in his wake a lineage of atmospheric scientists who've benefited from his leadership. While I knew peripherally of Joach's involvement with the space program, I just want to say briefly, again, at risk of stating the obvious, there's a whole generation of us - I am one of them - who benefited as kids, as children, from having the space program to look up to, as it were. I just want to take this opportunity to thank Joach as a representative of that for the contributions they made to spring-boarding many of us into the sciences. Joach, thank you. (applause)

Jay Fein:
Thank you very much, Brad. Alan.

Alan:

Well, I'd like to make a comment for the record because I arrived in Barbados for the BOMEX experiment as a young 23-year old grad student. I was on my way to Herbert Riehl's first VIMEX experiment as grad student labor, so I actually got to see Joach in the BOMEX arena. Of course, I worked with him much more in the GATE experiment later. Joach, I had no idea of your role in the Apollo project. You may not remember, but I sat with you and Herbert Riehl on the night that they landed on the moon, and we only had sound there on Barbados. We had no pictures. (laughter) I'd just like to comment these many years later, 40 years on, that I shared that night with you. In your humility, I would never have known the role that you had played in it. I think Herbert Riehl mentioned just a little bit in one sentence. But, thank you. (applause)

Jim Moore:

Jay, let me say one other thing: Brad Smull also made a comment I don't think we could hear very well here. Something I thought of as I was watching this presentation is that Brad and I were both very young men at the time, watching the space program. How on earth would we know that one of the men who was pushing this and managing this was one with whom we were to become close friends with over the next 30 years? Remarkable. I hope that reflects what you were trying to say, as well.

Jay Fein:

Yes, Jim, you are absolutely articulate on what Brad said. That goes for many of us in the audience, myself included. I remember that day very well. Any other comments? Joach...?

Joach Kuettner:

Yes, I think I mentioned before that if you had to do with the astronauts at least it's the first seven that I know very well, that there was not any great event but that they were as simple as you and me. I'll give you an example of that. After Neil Armstrong landed on the moon, he had to make several visits to other countries; I think it was ordered by the government to do that. One of the first countries he traveled to was Germany. NASA asked me to be his escort on this mission. I want to tell you that he was as simple as you and me, nothing of any distance between him and me. I spent several weeks with him. I think everybody knows that Neil Armstrong is a very humble person. I had another question, but it had nothing to do with space flight, so I will shut off here.

Jim Moore:
Go ahead and ask the question. Go ahead.

Jay Fein:
It’s allowed, Joach!

Joach Kuettner:
I’m sorry, I’m 100 years old, and I have forgotten my question. (laughter) Ask me right away!

Jay Fein:
OK. Joach, we’re going to have a short coffee break here, and we will be back at 3:30, and Vanda, did you get your question? Do you have it now? If you wish to ask your question now, this is fine.

Jim Moore:
What do you think, Jay? Do you think this is quite an excuse Joach has given us? This is one we hope all to have it one day, don’t you think?

Jay Fein:
(laughter) Yes.

Jim Moore:
An excuse to say “I’m 100 years old, and I can’t remember the question?!” (laughter)

Ed Zipser:

People who know about acronyms can just look at that title of GATE Operations Director and recognize the reverence in which we held Joach. This is a great pleasure and honor for me to be here today to recollect a little bit about the huge influence that Joach Kuettner had on not just my career but on the career of literally hundreds, maybe thousands of scientists in a number of field programs. The scope of GATE, as Jay said, was truly huge, and it took me a while - we didn't have Google in those days, but Google helped me a little bit at finding some articles about GATE that I had never seen before. This is one that appeared in something like *Science News*. Many of you who were involved remember in those days the argument between big science and small science. It was said that any real scientist would just grab an instrument, go out in the field, go home and publish a paper and wouldn't get involved with hundreds of other scientists. But there was no choice in a program such as GATE. It had to be big. It had to involve a great number of people. As well as anything that I've ever read, this article stated some of the lessons we learned between BOMEX and GATE. Many things were done in BOMEX, a remarkably successful experiment, that nevertheless come under the heading of what you might call lessons learned; one of these led to the successful design of GATE. "For the data gathering portion of GATE" - I'm quoting from the middle of the article here -, "planners were faced with coordinating an exercise as complicated as any ever faced by a field commander at war, made increasingly difficult by a basic GATE rule that no day's activities would be finalized until the day before." And that was one of the lessons learned in the BOMEX experiment: no matter how successful it was, the aircraft operators were kind of in charge there, and when they said "You will lay out your flight plans days in advance, and you will follow them," we lost many opportunities in that program. And I swore that I would never be associated with that type of thing again, having flown through some of the most interesting weather in BOMEX but being forced to just continue right on and do something in a completely uninteresting part of the tropics.

For GATE, therefore, a large repertoire of possible missions was designed to allow for a wide range of weather developments. The program's planner set up a mission selection team: the international scientists who would pick options for each day's activities the previous afternoon. Those of us who have struggled to write papers about a field program three years later, as we now seem to have to wait to do, need to be amazed that Kuettner and Parker wrote this complete report less than one year after the end of the field phase. That's hard to do. When you show a map of the layout of the ships in GATE -- this is the third phase -- to today's students, they usually react in total disbelief because they understand the scope of the field programs we can afford today, and they don't believe that we ever did this.

This is the aircraft. The aircraft radius circles from the car. This is the list of ships that were involved in GATE. Hardly anybody believes this these days. This is the list of the aircraft; hardly anybody believes that either. This is a picture that shows only nine of the 13 aircraft laid out on the Dakar runway, and - even as much time as I had there, I look at that picture and say, "Wow." I was talking with Dave Houghton last night. Dave Houghton was one of the many, many scientists involved - Alan Betts was up here a little bit ago making a comment. Dave Houghton's job in the planning of the GATE experiment - all, of course, under the leadership of Joach Kuettner - was to define the needs of the central program. That is, that part of the program that was completely central to the overall mission of GATE and GARP, and that involved everything: the scientific objectives, the data management, the research, proper integration of the most important parts of the boundary layer subprogram, the radiation subprogram, the synoptic, the convection, the oceanographic. It was Joach's job to make sure that we carried this out and carried it out successfully. I remember Joach talking about this. He would always admonish us in his magnificent and friendly way, "Do not forget the scientific objectives of the central program."

So here is the organization chart. Every program, of course, needs an organization chart, but I call your attention to the top: the GATE Director, Kuettner, the Deputy Director, Tarbaey. This was fully international. The mission selection team is there, and it consisted of a member from each of about seven or eight or nine countries. The experiment review board - Dick Reed, Sitnikov, Suomi - played an important oversight role and so forth. Firm commitments from many nations - in other words, how did this get carried out? Adequate resources - you can't emphasize that enough - oversight from the review board, organization, planning, and a director with the scientific and human talents to make it work. There's a man up in the upper left, Dick Reed that we all miss very much. He was on the experiment review board, spent a lot of time before, during, and after GATE. We miss his contributions a great deal. I apologize for the dozens and dozens of people whose roles I'm probably not going to mention: Jim Rasmussen, my partner on the U.S. contingent of the mission selection team; a couple of ugly people in the lower right waiting for the GATE bus; Helmut Weickmann another person that we miss; Mazin, many of the Russians. This was just a typical group of scientists from many nations that were constantly working together before, during, and after the field part to make sure the things worked. My particular role in this was to write the GATE aircraft plan, which was certainly one of the more complex things I've done in my life. At Kuettner's insistence, it was four years in development. Although it certainly jibed with what I wanted to do, consultation with all the sciences, and meetings, many meetings in many different parts of the world were required. Then for two weeks, it took a final writing in the John Scott House at Bracknell. Apparently a lot of the other subprogram scientists did not have the experience that I did. During the two weeks that I finalized the scientific part of the aircraft plan - Joach may remember this - the John Scott House at Bracknell was in the cold and dark. At 3:00 there was an industrial action that winter in England of the sort that often happens in England, and at 3:00 in the afternoon it gets dark in December or January. Joach came in and said "Everybody has to go home now because we have to turn out the lights." And I was incredulous. I said, "Well, I have all this stuff spread out to do! I can't write the aircraft plan in my room above the pub in the dark!" And he said, "That's exactly what you're going to have to do," and I had to go do it. We only had a few hours a day that we could work in the John Scott House. A full dress rehearsal for the aircraft program at NCAR, a full week, turned out to be one of the smartest things that we ever did, with everybody playing their role including the Russian pilots, the French pilots, and the air traffic control people. This was a real lesson learned. I hope you all memorize this - the main product of the aircraft plan: a whole set of missions that we were going to carry out. Fortunately, we could simplify it to the basic GATE missions. One of the things that you can do when you have enough resources - and some goodwill, and a little bit of luck with the weather, although we didn't need too much luck – is virtually every one of the missions was not only carried out successfully but in about the right number. So the planning did pay off a little bit better than another famous "mission accomplished" that some of us know. (laughter) Let's look back at some of the people who did this.

This comes out of the Kuettner and Parker writings. You've all seen this picture before, but - let me go back for a minute - the first summary there said "This exhausting effort could not have lasted a day longer." And, you know, in all the time that I watched Joach at GATE, I never saw him snoozing like that, never, but apparently even Joach got tired once in a while. So how do we develop confidence that the data from all these aircraft could be trusted? We did something that probably nobody would have the patience for today: all the aircraft and all the crews came to the field two weeks early, did tower fly-bys, did inter-comparisons, including some rather tricky and potentially dangerous triple inter-comparisons; some of you may remember the nail-biting. Here is the incoming AMS President, (laughter) who was obviously in training for her job on the Electra here with Al Miller. This picture here is not from GATE, it's from the NCAR Buffalo a couple years earlier. This is before Peggy realized that we would be happy to let her on the airplane without a firearm, so she didn't have to threaten her way on board. Here is a part of the Mission Selection Team meeting on a particular day; it turned out to be day 220 - we all learned to talk in Julian days - and for those of you that remember a little bit of history, just as during BOMEX the moon landing took place, during the middle of GATE a very important event took place, which we had to read about in French: the resignation of our President. And many of us hoisted many glasses to toast the occasion on that particular day. (laughter)

I wish I had more pictures, but the time is limited. I just wanted to get toward the end. Here is our friend, Bob Grossman, who has changed his hair color since this particular picture was taken, along with Joanne, obviously either planning a flight or looking at the satellite images from a previous flight. I love this picture; Peggy LeMone and I used it, and Becky Meitin, as well, in a paper that we wrote on one of the GATE days that I think is one of the more interesting papers. One of the reasons that we know what we know about that particular weather system is that Joanne, as a mission scientist, took a seat in the NCAR Sabreliner, which was not supposed to be a long-range airplane. She flew all the way to the GATE array and did four passes across this cloud system. I still have the original of this photograph where she found the hottest towers. It turned out that the evidence that Joanne gathered in that one Sabreliner flight has been used in probably dozens of papers since then about the difference between a convective cloud top over the ocean and the very low radar echo that accompanied it.

I want to close by thanking Joach Kuettner, and all of my hundreds of colleagues in this program and beyond, for the superb scientific leadership that you set for several generations of scientists, the personal guidance and encouragement that helped me develop and carry out my own role, and for demonstrating the importance of treating all participants at any level with calmness, fairness, and respect. This is part of the secret of your success and an object lesson for all who have known you. I want to add one thing: during those miserable weeks in Bracknell, while writing that aircraft plan, Joach and Monika invited me to their home and introduced me to the Sibelius 2nd Symphony. They introduced me to Murray Perehia, and he encouraged me to go down to downtown London when I had an off night and learn about one of the outstanding new pianists that I have loved ever since. So it’s not only, as many people here have said, Joach’s scientific success, it’s especially his success at dealing with people and in being such a wonderful human being. Thank you, Joach. (applause)

Jay Fein:
Thank you very much, Ed. Are there any comments or questions from the group here? Joach, would you like to say something first?

Joach Kuettner:
Listening to the last speech, I would like to make a short comment on how it looked from my side in GATE, and I’ll try to spend only a minute on it. One of the main memories that I have from GATE is the role that Ed Zipser played

in this project. He did not mention a few things that I feel were very important. He and (inaudible) designed some topical flight missions, before GATE started, and he invited a few of us, including me, to react to the missions, which were centered around artificially created weather situations. He will remember that, but he will not remember apparently how vital that idea was. We tried to solve some topical situations that they had designed, but it became clear to me that the idea was so good that it would work, but only when we invited the other nations. Of course, there was a large team from the Soviet Union, which at that time was the beginning of the Cold War. There were other complications like the tankers. The fuel didn't go anymore through the Suez Canal but had to go around Cape Town, and then come to Dakar where we were. Anyway, it became quite clear to me that we needed foreign nations to be fully represented, and this was where Ed Zipser became a very important part of GATE. The original idea of the mission selection team came from him. It had to be constructed to be sure that each nation presented somebody who not only understood the scientific problem but who could manage to avoid friction. So the mission selection team in GATE was formed according to the ideas of Ed Zipser and also Alan Betts. The main result was that practically no frictions occurred. It's always a very difficult thing to agree about a mission on the next day, which they had to do. I remember that as one of the keys to the success of a major experiment, whether it's in the Tropics or somewhere else. I want to thank you, Ed, for the contribution you made to GATE. Not everybody knows that. (applause)

That is fist comment I want to make. The second comment is one of the questions that I forgot with my memory of 100 years. That was your question of the relations -- it was actually Renata Brummer -- that raised the question, or it came from the audience, the relation between the, let's call them normal people, and the astronauts. I have already mentioned that there was no problem from the very beginning; they were just like everybody here, and their role didn't affect any decisions that were critical. But it was another relation that was more important and actually in the beginning of the Mercury Redstone project bothered me because I hadn't anticipated it. Up to this point, before the astronauts were named, the... (pause) Remember, 100 years. (laughter) Before the astronauts were named, we had to get together, the scientists or engineers connected with the launch vehicle, a completely different technology and the mint version of the program. And when I got into Huntsville and got the authorization to lead the Mercury Redstone - not yet Mercury but the manned program - to my greatest surprise, there was a strong disagreement between the engineers and the scientists. Of course, a program like the first manned program required all kinds of solutions to questions which you would be surprised at how many and how important. No, it was that the scientists, in general, who had an attitude of saying, “Oh, these engineers” - this was the other half - “these engineers are not really interested in why something works or doesn’t work. Shouldn’t they, as engineers, do that? They never ask the question ‘Why is something functioning?’ If something functions, that’s the solution.” And, of course, if you manage a program like that you have to deal with just as many engineers as scientists, probably with more, so you have to work very closely with them. I didn’t really have sufficient background to solve some problems there. Now when you talk to the engineers, they tell you, “We don’t need all these scientists around here. (laughter) They always want to know why something works. We are only interested that it works.” And certainly it took me a considerable amount of time to try not only to merge these two groups in the frame of the programs that they had but also to convince them that if a scientist asks “Why does this work?”, that must interest you, too, because you want to have it work, also.

I mention this only because that was the larger problem than the relations to the astronauts. And by the way, after Neil Armstrong had landed on the moon, NASA wanted him - not only NASA, probably the government, Secretary of State, et cetera - to improve relations with foreign nations. He was asked to go to Europe first. If you knew Armstrong, which perhaps very few did at this time, but I did, then you were not surprised that problems would develop. So I was asked to escort him on his first trip to Germany. We traveled together like any friend of yours would travel. We shared the hotel room, and while Neil Armstrong didn’t talk much, he answered any questions that I had. He was a very simple, straightforward man, as I think most of the astronauts were. I just wanted you to know that. Thank you.

Jay Fein:
Thank you very much, Joach. Bob?

Bob:
Hi Joach, hi Monika. I wanted to point out another important thing that occurred in GATE, again attributed to Ed and his group, and that was in each of the missions we had a primary mission, and importantly, we had an alternate. Both of those missions were ready to go so that if the primary day didn't show up as we expected, we at least had a fallback. That to me, throughout my experience in aircraft operations, was an important new addition. That didn't happen in BOMEX, but it happened in every subsequent setup that certainly Joach was involved in since that time. Ed, you and Joach had a lot to do with that.

Jay Fein:
Thank you. And Alan Betts, please.

Alan Betts:
Well, this is one of those moments when I feel obliged to fill in a little bit of the record. GATE went forward with astonishing optimism. It was really driven, in many ways, by the desire for a unifying scientific project during the Cold War years. I got drawn into it, again, very young, because incredibly at 15, 16 months before the first phase was supposed to begin there was no convection subprogram. The convection subprogram (laughter) was an integral part of the experiment.

I was just filling in a little bit of the background about how GATE was an extraordinary experiment carried forward with a great deal of faith and optimism in the face of the many obstacles that Ed commented on and which I'm sure Joach Kuettner is well aware of. I got drawn into it 15 months before the experiment with only the experience of tropical land experiments, and no experience of aircraft operations whatsoever, because there was no convection subprogram. We had central programs and the synoptic component, but the experiment was designed to address the issue of the interaction of convection in the larger scales along with the parameterization problem. I got drawn into the aircraft program with Ed Zipser. I also want to mention one other person who had a major role, Steve Cox, who'd been on a couple of BOMEX and (inaudible) before that; he and Ed were really my mentors. Another hidden strategy in GATE that is worth commenting on, historically, is there were two levels of international scientific management of that project. The first was the operational one that Joach chaired with such wonderful finesse and scientific skill. The second was the mission selection team. Before the experiment, Steve Cox, myself, and Ed sat down and discussed how the experiment really should operate. Could we, on a daily basis, put these relatively senior people in charge of running operations? Steve Cox said "No way will it work, no way. The international group of scientists should meet before the mission selection team and analyze all the options and present the mission selection team with a selection that they can approve." It was amazing how that worked. Joach owes a great deal of thanks to Steve, because he chaired that mission selection team of Russian, French, British, German, and U.S. representatives and helped steer them to understand the science and the relationship to the objectives of GATE. In many ways it was really a fait accompli from the international scientific group of the subprogram scientists. But thank you, Joach.

Jay Fein:

Thank you very much, Alan. OK, we'll have one more short comment, please.

Becky Meitin:

Jay, this is Becky Meitin in Boulder. Could I add something?

Jay Fein:

Yes.

Becky Meitin:

Another perspective of GATE: I was there just as a student, and I knew nothing about all of these intricate plans that had gone into doing this. But I would sit there every day in the mission selection planning meetings and watch this genius of a person, who was Joach, managing these hundreds of people from all different countries. Eventually over the several months, we realized what a major undertaking this was. I was always marveling at how diplomatically he was able to handle everything that went on and what a brilliant person he was. I never imagined sitting there as a student, that 33 years later I would be working for him.

Jay Fein:
(laughter) Well, thank you.

Becky Meitin:
It was partially thanks to Ed Zipser that I came to Boulder, by the way.

Jay Fein:
Thanks very much, Becky. One last comment please. Yes, Dave.

David Houghton:
Joach, I just want to add my thoughts and appreciation to you for your leadership in the GATE program to make it truly international. Bringing together the scientists in the Cold War period was an incredible accomplishment of yours. I want to thank you for showing how science is one way that we can help make a better world. Thank you, Joach. This is David Houghton. (applause)

Joach Kuettner:
Yes, thank you.

Jay Fein:
Thank you very much, Dave.

Joach Kuettner:
I wanted to mention one little thing -

Jay Fein:
Yes Joach, please.

Joach Kuettner:

- that was how friendships developed quickly in the GATE program, probably more than any other. These friendships were primarily between the Russians and the Americans, and I remember that... (pause) I don't remember. (laughter) Yes, these friendships have lasted almost through a lifetime in some cases. These were really warm relations that resulted from GATE, and the primary friendships were between the Russians and the Americans, probably in opposition to the political regimes of the countries. It was a very nice byproduct. I want you to know that.

Jay Fein:
Thank you, Joach.

Peter Webster:
Hello, Joach, it's good to see you sitting there. What I'm going to talk about are some of the Tropic experiments, but I want to make one particular comment - I've decided to call this *Following the Equator with Joach Kuettner: Expeditions and Experiments.* Bob Grossman and I have spent a lot of time talking about the difference between an expedition and an experiment. It will become clear in a little while, because when you enter a field phase with not much knowledge, it's like a geographical expedition where you are inspired to think about things. I would say that when I look at all the experiments mentioned here - BOMEX, GATE - the definitive things in terms of my scientific career have been summer MONEX and winter MONEX where I played this marginal role, really - I was sort of a gadfly of some type. But they led on to a lot of other experiments - TOGA and TOGA-COARE, things that many of us who were in leadership roles later on learned from that. One of the things that might surprise you is that, in my opinion in terms of relative importance of expeditions and experiments, the most important thing is being there and having time to think, relative to nature that is around you. In a sense, those of us who have been lucky enough to be on the experiments with Joach have had that opportunity. I sort of worry now sometimes - and this is the old man in me talking - that you can't get the same experience looking at the output of a general circulation model. And so we try very, very hard to make sure that our students spend some ship time or experimental time. We still try and do that.

I'm going to very briefly talk about one thing in BOMEX, and then we have Joanne and Mike (inaudible). BOMEX was an idea of taking a grid point, a grid box, so to speak, and measuring cumulus convection within and to see whether or not you could parameterize clouds. I might add that we're still trying to do that. But it was an interesting idea, and I think in a sense that a lot what was learned, as was said before, on how to design a better GATE. GATE itself I won't say anything about because Ed did such a lovely job. I marvel at two things, and one of them is 40 ships, 12 research aircraft, so many different nations, so much planning, so much activity, and the data's still being used. It's a definitive program. But I think that one of the great things was the number of interlocking components. I use the term "interlocking" very purposefully there concerning the radiation that Cox did and the clouds that Betts did which were all, in a sense, interlocked for the very, very first time. It wasn't that we were doing a cloud experiment, it wasn't that we were doing an ocean experiment, it was an overall, holistic experience. I wasn't there, by the way. I came along a little later.

But one of the things that we did find was that the new satellite observations were marrying with theory at this stage. Look at the diagram on the left - which, by the way, is quite a recent diagram - it's Outgoing Long Wave Radiation, and it shows propagating waves off the West African coast. This married with the work of Matsuno and later with Ghil and some of the work I did. We also had theories about the developments of these waves by the late Bob Burpy, which was very, very important. So there was something to look at that was in the theoretical sense; you could test hypotheses for the first time with an experiment. And by the way, that's the potential vorticity fields; you get a kink and you get instability.

There were four or five different phases of the monsoon experiment. I'll tell you a little story later on about Bob Howz and myself. But the first parts were the Somali jet experiments, measuring the Somali jet stream and also the Somali current - that is over here - and then for the first time - I'm not quite sure, maybe the last time - the aircraft flights over the empty quarter of Saudi Arabia looking at the heat load. There's a lovely paper by Donna

Blake on this. Then there was the Arabian Sea experiment, and then the Bay of Bengal experiment. One of the things I will point out in a moment is that we did not understand the intermittency of the monsoon. The Bay of Bengal experiment was unfortunate for two reasons. One is it didn't rain for the whole month, except for the three or four days when we declared there to be a break in the experiment. So people were very upset. We all went on a trip, and of course, it rained 6-8 inches over those two days. The second thing was it was a time when one of the Skylabs was approaching Earth and about to re-enter the atmosphere. We were very worried because the press in India had described this as a purposeful attack of the United States on India. Then they found out there were U.S. planes in Calcutta. Every day we were getting an increasing number of people watching the planes come in around our security area. I really think that if the Skylab just missed out by two orbits it would have landed in India. It would have been a very, very difficult time for us.

I'll now talk about a couple of observations from the winter monsoon experiment. The idea was to try and determine what influence the outpourings of cold air from Siberia had on the convected activity in the Equatorial regions. In my mind, MONEX was more defined by what we didn't know than what we did. But the questions that were raised but maybe not answered in MONEX, set the course of research for the next 30 years to an extent where I think we understand quite well some of the basic physics of the monsoon and even that we might be able to predict it. But I have to tell you that we did know something about the character of the monsoon. If you want to read a good book about the monsoon read *Chasing the Monsoon* by Alexander Frater. He said that the difference between the monsoon and the weather in Europe is the difference between the poor man and the millionaire. "Europe is the poor fellow. His habits are predictable, his movements restricted. Each day he will follow the same routine, taking morning coffee in the same restaurant, trudging off to a tedious job, going home to a bored wife" -- his book was written a fair time ago; it would now be to a bored spouse. "Indian weather, though, is extreme, willful, fast moving, and wholly unpredictable. Indian weather is a millionaire, the sort that will impulsively jump on a plane and fly off to London for lunch." And I thought about this a lot in terms of the monsoon experiment, and there are the things that one was finding out in the sense that this is different, this is very different.

Now, we didn’t know much about the interaction - and don’t worry too much about this diagram - it shows relationships between the monsoon and global sea surface temperatures, but we didn’t understand these things then. We had a little bit of a hint from the papers of Walker many years before, but we were looking at local processes rather than the grand scale of the monsoon. We didn’t know, for example, that the majority of rainfall falls not over land but over the ocean in the monsoon region. Shukla and I - he would never believe this diagram or any subsequent diagram until I showed him all types of satellite data - found that the maximum rainfall occurred in the Bay of Bengal. We understand why that is now. But we wouldn’t have known that without MONEX. A monsoon is a different type of animal than a big sea breeze. Also this is the active in the break monsoon. It’s a sequence, and that’s OLR. Red is dry, blue is - and you can see that this is not a mammoth scale oscillation of the monsoon, this is a composite, and you can see now the dry areas moving into the Eastern... Now here comes the wet area, and it’s going to bifurcate and move northward. And, of course, during the Bay of Bengal experiment, we were caught in a break monsoon, but we didn’t realize it. But knowing that was a breakthrough at the time, which made us ask the question. We didn’t realize that the whole monsoon is an oscillating system on a sub-seasonal time scale. So, good questions. We didn’t know - and this here is time versus cloudiness, rainfall actually, and you can see this is along 90 degrees east, and you can see here that there was a northward propagation and further northward propagation, further northward propagation. Now, the interesting thing is we didn’t realize how (inaudible) this is, because this diagram below is the northerly heat flux in the ocean. You can see this oscillates where every time we have an active and break period we have two to three to four petawatts of heat pushed towards the south. So this is a coupled phenomenon. We knew sea surface temperature had something to do with the monsoons, but these questions were raised earlier on. There was also a nice paper by Uninnayar and Joach on this very system here, which was the jet stream and the inertial instability of that jet stream. This beautiful paper, as a matter of fact, has inspired a lot of work that my group has done over the last few years.

Now, the winter monsoon experiment was to determine the influence of cold air on tropical convection. Bob Houze's project just installed a radar - I'm just going to show one result here in this little place in Bintulu where a beautiful radar platform was built. The plane flew in and they managed to drag the big radar off the back of the plane. The plane departed and then they looked around for the men with the crane; there was no crane. So for the next two or three months, this radar sat on the runway. So, one small hiccup. But the interesting thing about this diagram is that getting how little we know about the monsoon and what we've learned, these Equatorial westerlies are the result of an instability of the monsoon across the Equatorial flow.

One of the interesting and very important results Bob and Speed Geotis showed was that there was a strong diurnal variation. This we knew, but what we didn't know until they showed us, now, this is time along here and this is cloud amount here, and it's completely out of phase. And this is very exciting because it says that if you're going to model the world you'd better get this right, and I'll show you a reason why. This is from Jasmine a few years later, in 1999. What you can see is this right north and south up the Bay of Bengal. This is one of those northward cloud movements up through here, but now look at the diurnal variation. We were sitting here in 25 foot seas aboard the Ron Brown. Here at the northern end of the Bay of Bengal, every afternoon these squall lines would form, and down they'd come every day. So the important thing, as Bob showed also, is that even during a disturbed period, there's a very, very strong diurnal variation. You can see something very exciting on this one - this is just a little time later - these gravity waves will go all the way into the other hemisphere. They're traveling five or six, seven thousand kilometers as coherent entities. We thought that was very exciting. Also we spend a lot of time looking at fluxes and diurnal variations of heating and cooling. All these experiments point towards the fact that if you want to get the tropics right, you better get the diurnal variation right.

CEPEX I won't talk too much about. I imagine that Ram will talk more about that - an interesting experiment testing a hypothesis about the interaction of sea surface temperature and cloudiness and the negative feedback. I will say something about this experiment, because this is a new class of experiments, the Asian Aerosol Brown Cloud Experiment. But one of the very important things about this study is the anthropogenic influence on climate, but on a very short timescale. And assuming there is global warming, this is the type of influence on a very, very important system that man can have on a more rapid timescale. I won't talk anymore about this; I'm sure that Ram will.

The common factor in all of these experiments is the presence of Dr. Kuettner, who, I think, has been described in GATE as a field marshal. He certainly had more people at his disposal than most armies of most nations. But during those 50 years he's provided a steady and inspirational leadership for countless experiments. He's engendered an enthusiasm - he certainly has done it with me - to at least two generations of scientists, and he's mentored and encouraged scientific leaders of today. But during all this time he has kept one secret, and that is the secret of eternal youth. Jay Fein and I used to worry, why was it that we got older and older and older but Joach never did? He just stayed the same. So somewhere there was a secret elixir of life that he had. When I look back - this is now a long time ago, 25 years ago - Kuettner, Shukla, John Young, Joach and me, we've all very, very much changed, but there's one person in that picture who hasn't changed, and we want to know why.

Now, I have to tell one story. This is Bob Houze and I very elegantly dressed on the right-hand side there. At one of the first big planning meetings that Bob and I went to in New Delhi, we were so excited; it was our first trip to India. We shared a room, and it was on a back alley in the hotel. In retrospect, it wasn't a very nice room. We rushed off, had breakfast, went back to our room, grabbed our bags, and got into the lobby of the hotel. Joach was walking out. He said, "Gentlemen! Coats and ties, please!" We looked at each other and we rushed back to our room. Suddenly we realized we only had one tie and one coat between us. So each day we would alternate; I would wear the coat and Bob would wear the tie. And in fact, Bob, it's my turn with the tie. Please would you...? (laughter) So I hope you are very pleased, Joach, that we've been following your instructions ever since. Thank you. (applause)

This is just a couple of pictures. There's C.P. Chang and me elegantly dressed again. Later on we went into different programs. That's Kristnamurti there. That is Greg Holland, or King Gregory I as we call him, toga dressed. And that is John Young, who we always thought looked extremely saintly at this stage. And this is Bob Grossman through three stages of his life. (laughter) Now, I have to add that on a serious side, Bob and I have had a long relationship in various experiments. Bob and I worked very, very hard in Bangladesh for ten years. We've now finished that project, and this is one of the trips. That's not really Bob on the right. This is at the 25th anniversary of MONEX, three guys who are a little larger than they were some time back. And then we have a picture of Jay -- it's called the Jay Bouquet picture. (laughter) We have some luminaries there beside Jay - Dev Sikka on the left-hand side, who is an amazing man, still working very, very hard. I communicate with him probably every two or three weeks on some monsoon problem, so we enjoy that very much.

So anyhow, Joach, a lot of thanks for a marvelous trip over these last thirty years. We've sort of uncovered some of the mysteries of the Tropics, and we have at least found that there are so many more questions to answer. It's been a pleasure, an honor to work with you; it really has. But I think, Joach, it's time to tell us the secret about eternal youth. Thank you very much. (applause)

Jay Fein:
Are there any comments or questions from this audience?

Bob Grossman:
Joach and I were officemates after the GATE experiment, and during that time we talked a lot and enjoyed each other's company. Our friendship really

began there, even though we had met earlier during BOMEX. I was post-doc at the time and it was kind of scary at first - here's the Director of GATE and Project Mercury and BOMEX and everything. He's sitting across the room from me. But we talked and talked, and one day very similar to what von Braun did to Joach, he approached me and said, "Would you like to go to India?" And I had a couple of papers I wanted to get into, but just like Joach, there was an opportunity for some adventure, some satisfaction of curiosity, and the next thing I knew, I was in New Delhi. I was supposed to be the director of the international MONEX management team. The problem was no other people showed up. (laughter) I was pretty much it. I had some colleagues in Geneva that did come in. I had my great colleagues from the United States, and certainly my good friends and colleagues in India, especially Dev Sikka.

Just to put the MONEX in perspective, during MONEX Joach took the science and adapted it to the real situation. He put reality into our scientific endeavors. I guess that's the engineering part of him that came through, as well as the scientist. So first, that's what he did, and the second, which also has been mentioned, but peripherally and importantly: during these mission selection meetings, which were sometimes difficult because of having primary and alternate missions covering different situations, he was always there to remind us of the scientific objectives and how we had prioritized them. And he kept me going. I think Peter and I said he was sort of like herding cats, and that's really true. (laughter) But personally, he kept me going. I was all there by myself, pretty much, and those evening calls or morning calls from Joach, those meetings that we'd have walking down the street sometimes kept me in that program for over three years. Not only that, but during that time the Kuettner family embraced me almost as a family member. They'd invite me to dinners, they'd be very nice to me, and send me cards and so forth. But in MONEX, he took this complex and very sensitive situation and he made it happen. That to me was his crowning achievement.

One last thing, just a quick mention of his interest in the trades and the band structure of the atmosphere, horizontal roll vortices. He's written two seminal papers on that. And last but not least, since he was involved in stabilities and instabilities for most of his life - and here it comes (laughter), it happens every time I get a chance - the things that he dealt with, the instabilities, were only because he had a stable home life. He had a relaxed situation to come home to, a clean home, happy children, and that was because of his wonderful wife, Monika Kuettner. She should enjoy, and I hope she does, as much of the joy and honor we feel toward this man. She's a wonderful woman, and he couldn't have done it without her. (applause)

Jay Fein:
Peter, thank you, and Bob, thank you very much. Those were very nice remarks.

V. Ramanathan:
Thank you. Peter, thanks for the wonderful talk and waking people up. I was getting worried. Very good. Jay and others, thank you so much for organizing this and inviting me to be a part of this great occasion. I have a slightly different story to tell. Joach had basically a transformational experience in the way I do science, and hopefully, in a small way it impacted climate change research, so I'm going to go more from the science side. And Jay, I'm not an astronaut; give me a red flashlight when I get close to my time. Give me a two-minute warning, because there are certain important things I need to get to!

To my American colleagues I'm known as a theoretician, but I need to make a confession. I started out as an experimentalist, and I built this interferometer. It was the most foolish thing to do for a Masters' thesis, but that's another story. It's still working, but it was such a painful experience that I said I would never again touch an instrument or do an experiment. So I came to the U.S., changed my field, and was mentally doing theory until I got involved in this problem, climate change. I thought, if we talk about the greenhouse effect, we should measure it. I just so happened to know a few folks at Langley, and they got involved with me in this Earth radiation budget experiment. This is the satellite. It turns out measuring the Greenhouse Effect is the simplest thing you can do with Earth radiation budget satellites. Let's talk about the ocean. The ocean emits energy - let's say we call it heat, and the satellites measured what's going out. The difference between the two is the Greenhouse Effect. That's the atmosphere, the atmosphere traps heat. So it was a simple thing. I was surprised it had not been done before. I first thought of this as an undergraduate student at Chicago. When we produced this map, it shocked me because the energy trap was so close. For reasons I'm not going to get into, we can't do it all at the land where we really need it. (laughter) That's the nature of many things. But there is remarkable coincidence between the two. Then we planted the Greenhouse Effect. You know, we normalized it; I'm not going to get into the detail. Basically, it means 30% of the energy is trapped by the atmosphere; that's the Greenhouse Effect. So this basically followed what Manabe said, that the water vapor Greenhouse Effect - as the temperature warms there's more water vapor, it traps more blah, blah, blah, go on. Except they found this huge anomaly, which is now called a super Greenhouse Effect. As you know, in science you learn more by focusing on anomalies, not things which behave the way you expect them to behave. So we started going to the anomaly. They all come from the western Pacific Ocean, and the Greenhouse Effect theory tells you if it is a super Greenhouse Effect, things should be unstable. It should be warming up, heating up. But when I went to the Western Pacific Ocean something remarkable happened - I am not an oceanographer, but as you know, there are huge temperature gradients in the ocean, north and south, east and west. But once you hit 302, the ocean doesn't want to heat up anymore. It simply wants to expand, and it's now called by meteorologists the Western Pacific Pool. So we were curious what was heating the ocean.

The other major thing I want to mention is that even during an El Niño - I learned about El Niño after I got involved in this experiment - even during an El Niño, the ocean respects very dutifully the temperature of 302.5-303. It'll warm up to 303, and that's it. So we wanted to know what is causing the break. To double up the hypothesis, we looked into the El Niño of '87 - that's the ocean temperature warming, the atmosphere Greenhouse Effect increased - this is all coming from satellite measurements - and, of course, the clouds trap radiation in the atmosphere. But, because of the Rossby radius of deformation, the Equatorial atmosphere can pump heat instantaneously. So we said that heat is locked to the entire atmosphere.

We speculated that the clouds are cutting down sunlight as much as 50-100 watts. That's the cloud forcing or the cloud reflection or break on the atmosphere.

This was published in *Nature*, and I must say I was quite surprised and shocked at the amount of debate. Sometimes it became acrimonious, and I take responsibility for the acrimony of the debate. But so many tropical meteorologists are against it, and to irritate them more I started calling them the unifying hypothesis - basically unifying the tropical meteorologists against it. (laughter) Another quirk of fate brought me in touch with Jay Fein, and I explained to him what was going on. You could see the worry in Jay's face. Many of you, particularly UCAR friends and the climate friends, know how much he has helped climate science by promoting the modeling theory experiments. Jay said something has to be done. Ram needs help. And the help came along. Jay introduced me to Joach Kuettner. Although I was at NCAR for ten years when Joach was doing all these great things, I was oblivious to all that. I learned several things from Joach - I still continue to learn from him - the first thing which impressed me about Joach was his incredible curiosity. I learned from him the power of listening, and the second, how to ask questions which would promote and bring information, not put people on the defensive. This was a pretty acrimonious issue at that time, and then slowly, it was accepted. Joach became my student in climate research, and I became his student in field experiment. You can guess who got the better deal. (laughter) I learned a lot more about field experiments. Basically the two of us - and Joach pretty much led the way – in three to six months doubled up this experiment. Peter talked about TOGA-COARE, which was happening at that stage, and I had an entirely different way to test the hypothesis. But Joach persuaded me - correctly, now, later I realized – that you have to go from the heat budget of the ocean. He said, "Your argument involves heat budget; you've got to measure that, and the issue of evaporation." I'm not going to go into all the details of it. As you know, thanks to NSF and UCAR - Karyn Sawyer's here, and her colleagues did a great job as the funding was done at a remarkable speed. Within a year the whole thing was hypothesized, proposed, and we were in the field.

And what did we learn? I'm going to keep you in suspense until I go to the end to see what happened to the fate of the thermostat. But what we learned there was not what we went to see; we couldn't close the gap. After doing the heat budget, we found that the sunlight reaching the ocean from our models was about 20-30 watts more than what was really happening. We didn't know what was going on; something in the atmosphere was trapping sunlight. We had to go on a side tour to figure that out. Again, Peter mentioned the Indian Ocean experiment. We basically launched this around the pollution idea to see if it was pollution which was absorbing so much sunlight. Again, I went to Joach. He was pretty much the chief scientist of CEPEX. Here he helped me out in designing the experiment. We discovered something totally unexpected. We went there proposing man's pollution, and the reviewer said, "You're not going to see anything in the Indian Ocean; the Indian Ocean is the cleanest ocean on the planet!" (laughter) We found during the dry season it's the most polluted - you can see a river of pollution flowing down the Bay of Bengal and the Arabian Sea. Of course, we found what we were looking for in terms of absorption. You can see direct sunlight made of a ship, these measurements, in and out of a plume. This particular pollution can reduce sunlight by as much as 30-35 percent. It was a huge amount, much more than the 20 watts we were looking for, but then, of course, it was also scattering. So we had to add it all up and finally track down that this 15-20 watts could come from pollution, the particular pollution of black carbon or soot, the same stuff you see coming out of diesel trucks. Then we had to set up huge surface observations to track this down to make sure it was not just germane to the Arabian Sea. Now we know it's common to all pollution absorbing sunlight and going on. That was the 20 watts; it's now called global dimming.

But we also found that in the atmosphere, this dimming was coming from black carbon in the air trapping an enormous amount of sunlight. By that time I had worked with Joach for over ten years, so I knew this was basically inferred from models. We couldn't trust it; we had to measure it. To measure this with an aircraft, you need at least two or three. I knew it was almost impossible to get manned aircraft, so we started thinking about unmanned aircraft. Knowing very little about UAVs, I was going after an unmanned aircraft which would go from San Diego to Hawaii non-stop. That’s the only way it can go; there’s nowhere in between to stop. I went to Joach again, and he took me to Paul McCrady’s shop. We started thinking, dreaming about this huge UAV. Paul basically said he could build it. Unfortunately, he then became ill and passed away.

The UAV was lightweight and about two meters wide, wingtip to wingtip. These are remarkable machines. This UAV is probably one of the only good things to come out of the Iraq War. The UAV is a remarkable research platform. But it can’t do everything. It’s not any competition for manned aircraft, but we could see real images in real time. We could locate three aircraft, one on top of each other. The top one measured how much sunlight was coming in, and the bottom one was measuring how much went through, so we could use the difference between the two to get so-called flux divergence heating ray and track down the absorption. We tracked this pollution all the way to the Himalayan glaciers.

What I want to talk about this experiment to Joach and what I wanted to mention to you was how amazing it was how much he got into the aerosol chemistry and physics. It was his questions about distillation between dimming and heating that the UAV showed. It turned out in India the major source of black carbon is indoor cooking. So why am I focused on that? Basically, as you know, in the climate game we are really going fast towards unsustainable climate change. And how fast, I don’t know if it’s 30 years, or if it’s 100 years. We are on the trajectory, so a lot of us are thinking, “What can we do to buy some time and slow down?” It turns out black carbon is the second largest contributor to climate and global warming, so we’re asking how we can reduce that? This is my grandmother’s kitchen, by the way, and this lady bought her house. I was sad to see this picture was taken about three years ago - she’s still cooking the same way my grandmother cooked. This is a problem we can solve, and it could have a huge impact. By the way, roughly three billion still use cow dung and firewood as fuel simply because other fuels are not accessible or affordable. Our hope is to do an experiment, making detailed measurements before and after, so that you get basic measurements on this village and see how much black carbon is coming up. Then replace the cooking fuel, basically create a black carbon hole, and give them better ways of cooking. This is developed by Philips Petroleum with the fan, so it cuts down black carbon emissions; that's the solar powered lamp for the kerosene. Then we want to measure the impact on the atmosphere. The hope is - my theoretical works are just that - which I don't trust - that removing one ton of black carbon will have the same effect as removing 5,000 tons of CO_2. Imagine if this could be shown on a large enough scale. We want to do this on a scale of 50,000 in population so pollution from this village can be tracked with satellites. Hopefully, we'll see this hole, and if it can show its 1-5,000 tons of black carbon reduction, the amount of carbon credit which would come to this poor row of folks would be so enormous, that it would pretty much solve that problem.

I'm also saying this: I think we should continue Kuettner's legacy of field experiments. I think the time has come to do interactive field experiments, to understand better the workings of the atmosphere. So I conclude - Jay, do I have a couple of minutes? So what is the face of the thermostat? I basically decided after the debate my role was to produce the data. It's not up to me to test it; of course I would test it and say it works, but that's not going to have any impact. Anyway, nine years later there's a paper published on this, and they had a coupled ocean atmosphere model. They basically said in their model that although the dynamics were important and evaporation was important, the clouds provided the dominant feedback in regulating Pacific Ocean temperature.

Next is a paper by Peter Webster. I must say that of all the tropical meteorologists I've talked to, I have had the most constructive discussions with Peter. His paper reveals, if you'll allow - I'll give you a chance to rebut what I say, Peter, but please keep quiet until I finish my talk (laughter) - what Peter found was that in the Pacific Ocean, the thermodynamic, meaning the heat flux argument - that was my argument - is providing significant regulation for the large scale atmospheric circulation; I completely agree with that. That was part of my argument. If there was no Rossby wave, the system of long radius of deformation, I could not have made it stable. Nature could have done something. There are two things about stability that was a fault in our paper. We sort of put thermodynamic regulation, although I deduce dynamic regulation of the atmosphere. But what was pointed as significant was that the Indian Ocean was regulated by an entirely different mechanism, convection in the oceans, which tells me that there are many degrees of freedom to this complex system. So if it turns out that the dynamics don't work, then the thermodynamics will come into the picture. If the clouds don't want to cooperate, the dynamics will be there. But the intriguing question is why is the Western Pacific warm pool warming with such a great hurry. I'm thinking, what is happening to my thermostat? The Central and Eastern Equator Pacific Ocean is not warming, but the Western Pacific is warming. I am very worried about that because of the water vapor Greenhouse Effect.

In any case, the ultimate author on this was really Joach Kuettner. Joach created a model during the field project; that's what really floored me. By the time we finished the field experiment, he had a detailed model working. A lot of you talk about him as a glider pilot as the American model, but he was also a conceptual modeler of the climate, and he persuaded me that we have to really look at the effect of the (inaudible). This shows in that model. I was a co-author, mainly to keep Joach honest about some of the numerics. Otherwise, it was basically his baby. And similarly, it's the actual evolution of the temperature during our CEPEX experiment, just in the heart of the warm pool and this outer boundary. I think this model basically supports what Peter and I showed others saying, but this paper had an interesting history. I want to conclude with this. It was submitted in 1996, and I learned something remarkable. I was working with Joach during this time. There were periods of two or three weeks Joach wouldn't reply to me, so I used to tell my wife, "Joach is goofing off. What is he doing?" I later learned he was doing other field experiments with all of you! (laughter) In any case, this paper was submitted, and we got reviewers' comments. There was always disagreement, as I liked to call what Peter said, there's reviewer A and B who don't agree with reviewer C. We got a huge number of comments. We agreed on a modus operandi of how to respond to the comments, but then I had my heart attack a month after these reviewers' comments came. So then the whole INDOEX and the black carbon stuff took me away. Two or three years ago Joach and I talked about this. We said, “We should publish this paper, we should do something.” And I looked at the paper, and I didn’t want to change anything. He had done such a beautiful job writing that paper, it was masterfully written. And then when Joach reached 100, we talked about it. I told Joach, “Look, you tell me how to change the paper, what needs to be done.” And Joach said, “Ram, I read that paper. I don’t think I want to change anything in that paper.” So it’s still there. Joach, one day hopefully we’ll get it published. Thank you, Jay. (applause)

Volkmar Wirth:
Thank you. It’s a pleasure and an honor for me to be here at this very special symposium. So back to Joach’s roots, and this means back to Germany. I’m trying to close the circle of the symposium, in a sense going back to the earlier parts of Joach’s life. For this purpose I am going to lead you more specifically to the summit of the highest mountain of Germany, which is at Mount Zugspitze. This is a historic photograph taken in 1900. That is the year when the observatory was opened, actually, so the first measurements were taken on the 1st of August, 1900. That’s history which Joach used as an observer in the three years after the war. Here you see a photograph of Joach taken on the platform at this observatory. I can imagine that this was a very special suit of three years, like a very calm atmosphere being on top of a high mountain - imagine no email and so on. Joach himself remembered these three years later saying, “They stand out in my memory as a time of reflection, which can only be compared to the silence after a thunder,” the thunder presumably being the war. And certainly this situation led him to think and to reflect, and so he did. What does a renaissance man think about when he’s allowed to think? He thinks about flying. This is a picture taken from a publication he wrote during these years. It’s about the flying technique of certain birds he found in the high altitude. It’s a very interesting publication. He compares the technique of these birds in different situations to certain constructive details of aircraft, which this is something that he was certainly an expert on.

But that's not the topic of my presentation. What I want to talk to you about today, among many other things, is that Joach thought about banner clouds. This is a photograph that was taken by Joach of a banner cloud. This is a view from the summit of Zugspitze. The wind is blowing from the left, and the banner cloud can be seen on the right. This is the cloud. Joach made measurements; here you see him right on the ridge taking measurements. He used a simple device, just taking temperature and moisture measurements, leaning over to the one side, getting the cloudy air, and leaning over to the other side, getting the other air mass. What he found was interesting - the cloudy air is not only moist, it's also warm by comparison with the other air mass, which is not only dry but cold. The cold air is over rather warm air, leading to a very unstable situation. The temperature difference was not small but on the order of 4-5 degrees. A question was left, but the data apparently got lost when Joach went to the United States. When I heard about that problem, I thought, "This is very intriguing," and I wrote a letter to Joach. Later we met. This is one of the meetings in Garmisch-Partenkirchen. We started to discuss this problem, and soon we came up with a sketch and a sort of first hypothesis. We thought the first approximation that the Banner cloud is really a Prandtl's lee vortex that's getting visible because of the moisture getting into a cloud. We also thought along this ridge, which is essentially two dimensional, it's essentially 2-D dynamics. We shall see that this is partly true but partly wrong. Soon we realized there's a number of interesting science questions - it's not only the basic mechanism, what's the asymmetry due to? Is it mostly dynamics, or is there a role for a moisture asymmetry as well? How about the role of thermodynamics, the latent heat release within the cloud? Is that important? How about this very unstable stratification? Why don't we apparently see more of that? Also, what is the role of gravity waves? So then we thought this is enough to actually write a proposal, and we did. We wrote a proposal to the German science foundation with Joach as one of the authors. Miraculously, this proposal got funded. This is what I want to talk to you about. The first bit will be sort of preparations, and the second bit I'll try to mention a few of the results we got.

First, preparations. The first thing we did is actually something very simple: we mounted a web cam on this observatory looking westwards along this ridge where you often see banner clouds. That's really a very simple but very useful device to get, so one can observe statistics for the duration, frequency, and the size of these banner clouds. Just to give you an example - this is the view, and as I animate this, the wind is blowing from the right and you see the cloud creeping upward up until it reaches the ridge level, and then it's blown into the lee again. This is a nice sample of a banner cloud. You get the feel of a lee vortex in a sense. These web cams, these movies were so useful that we actually dared to write a paper, and we took the freedom to define what we think should be a banner cloud. This is a fun paper in an online journal. We also embedded a number of our movies, so look for this paper. But we installed not only a web cam but also real measurement instruments, two masts on both sides of the ridge here, the southern ridge and the northern ridge, so these masts are just about 20 meters apart measuring temperature, wind, and humidity on three levels. We also equipped the cable cars that exist on both sides of Mount Zugspitze with automatically measuring instruments. And last but not least, we had a model, a Large Eddy Simulation model, which is particularly suited to deal with very complex orography and has sort of an inflow, outflow geometry.

So what did we find? The first thing is sort of the question of two-dimensional versus three-dimensional geometry, so the first try was what we thought was essentially 2D geometry. This is the Mount Zugspitze on the left. The wind is blowing from the left. This is the valley of Garmisch-Partenkirchen, and the quantity being shown is horizontal vorticity. As I animate this you can see a sort of nice boundary layer separation of the summit of Mount Zugspitze and the intermittent vortices that are being shed into the lee. Since this is 2D flow, you can actually see that these vortices in a sense merge and form a large vortex that fills the valley over Garmisch-Partenkirchen. We thought, OK, this is nice, and this kind of resembles the sketch of Prandtl and we were kind of happy. But then we included moisture and could not get any banner cloud. After a while of thinking we realized, OK, we actually should not get a banner cloud in this 2D situation because there's no way for the parcel to get around the mountain, because each parcel, with 2D geometry, has to go over. So as the parcel rises, the relative humidity goes up, and then it gets caught in the lee vortex going down, the relative humidity goes down, and then it's going up again when it rises. But the relative humidity on both sides of the mountain has to be the same if the parcel is sort of conservative. So you get either a cloud on both sides or you get none at all, but you would not get a banner cloud, which means only on the lee, not on the windward side. So far so good. We went to fully 3D geometry. As our first approach we took a pyramid, which is sort of a paradigmatic obstacle if you want to have an isolated mountain, and lo and behold, now we got a banner cloud. This is a moist version of our model simulation; the top panel shows sort of a side view, the bottom panel shows the top view, and the quantity being shown is sort of an iso-surface of cloud water content, and the coloring is the vertical wind. And as you animate this you see a nice banner cloud, the cloud in the lee, so the wind is blowing from the left, and it's kind of in stationary but in the time mean, this gives you a banner cloud exactly where you expect it to be.

So what's the basic mechanism? With a model you can start playing games, and the first thing we study is really dry dynamics. We thought in a quantity that must be important in this game is sort of the Lagrangian vertical displacement. At any point in the domain we diagnose the Lagrangian vertical displacement of the parcel that it has suffered since it entered the domain, so that's Delta Zed. If you plot this quantity, there's a very pronounced lee windward asymmetry, giving a large value of this Delta Zed in the lee but not large values on the windward side, which means the parcels on the lee came from further downward compared with the parcels on the windward side. This at least suggests that you might get a cloud in the lee but not a cloud on the windward side because vertical parcel displacement is sort of conducive to cloud formation. If you now plot an iso-surface of this quantity, Delta Zed, this really looks like a banner cloud, and if you're looking for a mountain that looks like a pyramid, this is Mount Matterhorn in the Swiss Alps. That gives you real banner clouds, which I suggest is not too bad.

But, of course, there’s more to it than just dry dynamics. To form real clouds you need moisture, so the point you have to get is actually that the lifting condensation level of this parcel number two must be below the summit. But the lifting condensation level of parcel one must be above the summit. It turns out that you can get that. This is profiles of potential temperature and of water vapor mixing ratio in the typical situation where you get the banner cloud. It turns out that the right panel shows that what we’re using in the model is kind of an idealized version; you want to have slightly increasing moisture as you go down, and the temperature of the stratification may be neutral or slightly stable, but that’s not so important.

Next point, what about the impact of size and shape? We did a number of sensitivity studies and varying essentially the height of the pyramid and the angle of the slope. I’ll not go into the details so it’s systematically varying these two parameters. The bottom line is that for good banner cloud formation, you essentially need a high and steep mountain. This is perfectly consistent with observations; you often get banner clouds on Mount Zugspitze, on the Matterhorn, on Mount Everest, on Fitz Roy. These are all high and steep mountains.

How about the impact of diabatic processes and gravity waves? I’m not going into the details of this. It turns out that although these aspects are giving you a 30 percent modification and are important, they are not key ingredients. The only thing I still want to go back to is the difference between the windward and the leeward air mass, because that’s the work of Joach 60 years ago. Just to remind you again - you get cold, dry air above warm and moist air, leading to a very unstable stratification. With our instruments we had an intensive observation period and measurement campaign. The eleventh of October 2005 was our golden day, and with all the instruments working, a nice banner cloud developed. This is what I’m going to show you. Now, the bottom panels show you the temperature measurements on these two masts. They’re just 20 meters apart, one on the southern side and the other one on the northern side. Twenty-four hours’ worth of temperature measurements were taken. Throughout most of the day the temperature was essentially the same, except for the hour or so during which the banner cloud was there. During that very time the temperature on the northern side, the cloudy side, was about two Kelvin larger enhanced; this very much reproduces the measurements of Joach 60 years ago. And again, this is also reproduced by our model simulations. You have a temperature excess at the location where you observe the banner cloud, and comparing a dry and a moist model shows you that this is essentially the latent heat release within the banner cloud. The quantity shown here on the top is actually a virtual potential temperature, which tells you that this is an unstable situation. If you compare these two runs, you find that the turbulent kinetic energy in the moist run is actually enhanced compared to the dry run, so again, this is consistent with the unstable stratification.

Let me come to the conclusion. Overall, I think this was a very successful project, but it was not only a successful project; for me it was unlike any other project I had. That is because it was tied to the work of Joach 60 years ago, and if anything, it showed me that, on the one hand, the methods that we are using have evolved drastically, both in terms of measurement possibilities and certainly the modeling. But on the other hand, the science hasn’t really changed so much, and with this I mean finding the right problem and asking the right questions. This is something Joach clearly taught me. He gave inspiration to this project. He gave motivation throughout the years. We met at Frankfurt at the airport. He came to my institute in Mainz, we met in Garmisch, we went to Mount Zugspitze, and without him this project certainly would not have happened. Thank you, Joach, and thank all of you for listening. (applause)

Jay Fein:
Thank you very much. That was a wonderful talk. And I’m going to ask if there are any brief comments from the audience here, or from anyone at Boulder. (pause) OK.

Boulder:
Not at the moment.

Jay Fein:
OK, thank you. And I want to do two more things before bringing this symposium to a close. I very much regret not including one more aspect of Joach's life that was not touched upon today but has been fascinating to me. You all who are perhaps of my age may remember that in many ways the state of New Mexico was made famous because of UFOs, (laughter) and when I was a child - well, when I was a young man - UFOs were a big mystery, and I'm reminded of this because Ron Smith answered a question of Joach's a couple of hours ago. I don't know if Ron's still here... Yes, he is. When Joach asked, "Is the rotor problem solved?" I guess at the time it was "Is the Bora solved?" The rotor wave, excuse me, yesh. And one of Ron's comments was, well - he waffled, but he said a nice thing; he said, "Any good scientist must know how to ask the right question," and that's very important and very true. A publication by Joach called *Quo Vadis: Science and the UFO Problem*, was published in 1975 when Joach was chairman of a group that was established, I believe, by the American Institute of Aeronautics and Astronautics. I'm going to read very briefly from this. As you may remember, there was a lot of mythology and urban legend, and some would seem like very credible reports about UFOs. This is the quote: "The time has come to recognize that sufficient observing material exists to answer the question whether or not the UFO phenomenon presents a legitimate scientific problem and how it can be defined in clear scientific terms. I submit that this has not been done and that as long as it has not been done, all attempts to interpret the phenomenon will remain speculative in the eyes of the scientific community." And he goes on from there. The question he raised was not "Do UFOs exist?" He asked the right question, and interestingly enough I learned a few days ago that he wrote a postscript to this paper in 2001 where he basically criticized his thoughts expressed in the paper in 1975. I find that a fascinating collection of papers to read, and you can Google them, (laughter) if you wish. So I'm happy to at least enter into this day one other aspect of your life, Joach, which has not been touched upon. At that, I would like to ask you, Joach, if you would like to make any closing remarks.

Joach Kuettner:

After such a session, it is not possible to make remarks about every paper. Actually, I didn't realize that I wrote so many. (laughter) But you must admit that the subjects are interesting. You know that I have passed 100 years, and if you look back at your life, you see it like a picture of mosaics. You know what I mean with that, I hope. But each mosaic is an encounter with a colleague, with a scientist, with a philosopher, et cetera, and only when you realize that a mosaic is kind of a picture where each little stone has a different color, and altogether then make up a picture. I didn't expect at all that you would have so much information about things that I have been concerned with, but I would like to tell my conclusion: that if you have the opportunity to collect these little colored mosaic stones, one blue, one white, that they may in the end add up as something worthwhile doing, and that is really what I have tried to do in my life. But I have never heard such a combination of talks in which I was involved until I heard it today. As I look back at my friends, those that are still around and those that have left us, I can only say that I feel today as the owner of a beautiful mosaic, namely your contributions. I would like to thank each speaker for surprising and overwhelming me, and that applies also and primarily to Jay Fein, who's our Chairman here, who has been my respected friend, and all the others like Renata Brummer. I cannot pick out an individual one because there are too many. But thank you so much for summarizing my lifetime. Thank you, Jay, for a perfect session. Thank you. (long applause)

Jay Fein:
Thank you very much, Joach. I want to express deep appreciation to all the speakers for wonderful talks, as Joach said. I want to thank the organizing committee. I want to thank Vanda, in particular, for being both a speaker and a great help on the organizing committee, and the rest of the committee is identified on your schedules. I also want to thank Karyn Sawyer, who's sitting here, and let you know that there's one last activity that I would like to introduce, and this activity is kind of special. Karyn and Susan Montgomery-Hodge and others put together a special book for you, Joach. The special book contains many photographs, but most importantly, it contains notes and letters from many, many, many of your colleagues and friends from

over these years. I wish you great joy, you and Monika both, when you're sitting around the fire during February reading these together. May I ask, please, that Don Lenschow, who should be currently there in Boulder, present to you the book. Don?

Don Lenschow:
It's my great pleasure to give you this book, and a great honor to have been a colleague of yours, for all the advice and all the friendship over the years. Thank you.

Joach Kuettner:
Thank you, sir.

Don Lenschow:
I just wanted to acknowledge personally the contributions that Joach has made as a friend and as a colleague over the many years that we've worked together and interacted. It's been a great pleasure and a great enjoyment to me. Very satisfactory results have come from all the interactions that we've had. Thank you.

Joach Kuettner:
Thank you.

Jay Fein:
(applause) This is (laughter) a cheap copy of the book, and the title of the book is *Joach Kuettner: Soaring Through a Century of Adventure*. Very nice title, Karyn. With this, I am calling the symposium adjourned. Thank you all very, very much.

Boulder:
Thank you, Jay.
(applause)

END OF SYMPOSIUM