

Bay Area Air Quality Management District
939 Ellis Street
San Francisco, California 94109

APPROVED MINUTES

Advisory Council Technical Committee
9:30 a.m., Monday, June 9, 2008

- 1. Call to Order – Roll Call.** Chairperson, Kraig Kurucz called the meeting to order at 9:52 a.m.

Present: Sam Altshuler, P.E., Fred Glueck, John Holtzclaw, Ph.D., Kraig Kurucz, Chairperson.

Absent: Louise Bedsworth, Ph.D., Robert Bornstein, Ph.D.

- 2. Public Comment Period.** There were no public comments.
- 3. Approval of Minutes of April 7, 2008:** Member Altshuler requested minor editing to pages 3 and 6 and to correct the spelling from Bart “Kruse” to “Bart Croes”.

Committee Action: Member Glueck moved approval of the minutes as amended, seconded by Member Holtzclaw; carried unanimously without objection.

- 4. Past and Future Temperature World-Wide, in California, and the Bay Area:** *Dr. Philip B. Duffy of the Lawrence Livermore National Laboratory, will provide a presentation on historical temperature trends, possible causes, projected future temperature trends and their uncertainties.*

Dr. Philip Duffy, Lawrence Livermore National Laboratory, provided a technical PowerPoint presentation, that he hopes the Committee finds informative. His purpose is to inform the Committee of some issues and hopes to provide a better understanding of what we know and do not know, but said it is not definitive or prescriptive.

Regarding temperature trends that affect air quality in the Bay Area, Dr. Duffy said while we know a lot about temperature trends, the questions the Air District is asking are challenging, as the San Francisco Bay Area region is very small for global models. They usually deal with much larger scales, things get complex on small scales, and what really impacts air quality is daytime temperature trends in the summer, which is exactly what they do not understand.

Dr. Duffy provided his background, stating he is a physicist by training, has worked on climate research issues since 1990, he mostly does numerical computer modeling of climate, recently he focused on climate change in California past and future and societal impacts. Therefore, he considers himself to be a generalist as compared to many scientists. He serves as Director of a University of California Institute to study climate change impacts on air quality, agriculture and human health.

Dr. Duffy presented an outline of historical temperature trends globally, in California and in the Bay Area, covering the cause of the trends, a discussion of uncertainties and a summary, including thoughts for future research. He said temperature trends show a gradual cooling until the start of the industrial revolution and then a rapid warming which we now believe is due to increased greenhouse gases which are the result of combustion of fossil fuels. We do think that at least some of this warming is not of natural origin because of the high rate of warming during the 20th century compared to warming during previous centuries. Another reason is that computer models cannot explain the rapid warming at the end of the 20th century without including natural and human factors.

He presented an observed temperature trend (red line) going back to the before the start of the 20th century, and another trend (gray line) which is a family of computer simulations which do not include human influences and includes natural factors, but do not explain the rapid warming at the end of the 20th century. Similarly, the final panel is red and observed and the gray is computer simulation, including only human factors, but not some of the so-called natural forces, specifically solar variability and volcanos. Here, we can explain the warming at the end of the 20th century but not at the beginning. And the final panel shows the red curve is observed warming, the grey is computer simulations including both human influences and so-called natural forces. So the message is that, to fully explain the temperature history of the 20th century, we need to invoke both natural variability, natural forcings and also human influences. Because of analysis like this and others, we have increasing confidence that humans are changing climate on a global scale, and he presented three successive IPCC reports dated 1995, 2001, and 2007 on climate change with quotations expressing increasing confidence that at least some of the warming seen, particularly in the latter half of the 20th century is not of natural origin.

Regarding temperature trends in California, Dr. Duffy presented temperature trends over 50 years from 1950-2000, which identifies summer and winter and the daily average of the daytime maximum temperatures which occur during the daytime and the bottom row is nighttime minimum temperatures over 24 hour cycles. The panel results are from different observational data sets which are nominally equivalent. They are in rough, but not perfect agreement. In looking separately at summer and winter, and separately at night and day, there are very different temperature trends. Gray regions have no statistically significant temperature trend. If you compare each there is more warming in winter and if you compare the bottom row to the top row, there is more warming at night than in the daytime. The summer daytime trend shows no warming. This is the time and season that has most impact on air quality, but here they really do not see a trend. We think we understand that, but they are not completely sure. The Bay Area has similar temperature trends to the rest of the State. And, the State has similar trends to the western US region.

Dr. Duffy said the observation of warming we see with thermometers is corroborated by related observations. He presented 50-year trends in snow water equivalent, which is a measure of snow on the ground. Red circles show decreasing snow trends over 50 years, which is a consequence of warming. The message from this is that many of the regions with less snow have no significant trend in precipitation and the loss of snow is presumably due to warming.

The other thing they see which confirms the existence of warming is that if you look at the rivers that drain the west side of Sierra where we get our water supply from, the flow is

coming earlier in the year, which is consistent with warming which is consistent with more precipitation coming in the form of rain rather than snow, and it is consistent with snow melt happening earlier in the year.

Regarding detection and attribution, just because we see a trend, it isn't always due to humans. He presented Antarctica trends, said a year ago he looked at California temperature trends and questioned whether we think these are likely to be natural or human influences. They looked at observed rates of change of temperature and compared them to model simulations of the most rapid change in temperature likely due to natural factors. The results show a positive trend in nighttime temperatures that is warming over 50 years, an estimate of the most rapid trend which they believe is due to natural variability, and some non-natural factor must be contributing to this warming. They estimated the maximum warming possible due to natural variability by using model simulations, taking very long simulations and divided them into 50 year sections and looked at the simulated trend over time, developed a histogram of simulated trends due to natural factors only and they looked at the largest possible trend, which provided an estimate of a maximum rate of warming due to natural variability. They did this analysis for all seasons individually and for day and night and what is shown is more warming at night than in the daytime, there is more warming in winter than in spring and in summer daytime there is essentially no warming. They believe that in winter and spring, some of the warming trends are too rapid to be entirely natural.

Dr. Duffy reiterated that the Bay Area seems to share similar trends with the State of California. He looked at some of the station data and looked at nighttime/daytime, summer/winter trends, and they look similar to the data sections, which is there is generally more warming in winter and generally more warming at night.

Regarding what they believe is causing the trends, Dr. Duffy said the sort of climate models that are normally used to predict climate really do not reproduce what has happened historically in California. And this gets back to his point of that the Air District is asking him to look for what is a very small region. Climate models today are considered to have validity on the scale of continents and sub-continental scales even when looking at the scale of the entire State of California. He presented a slide detailing observations that the models do not reproduce observed historical temperature trends on the scale of the state of California.

Dr. Duffy presented and discussed the multi-observational data sets and nighttime, daytime, summer and winter trends, stating the models do predict some warming in the summer daytime. The key question is what is going on with daytime summer temperatures is historically, climate models do not reproduce what has already happened, which is a little disconcerting, but there are reasons for this.

The course-scale global models do not include a lot of the drivers or forcing factors that effect regional scale climate. Some of those are land use change, which includes irrigation and urbanization. In California, irrigation is a very significant driver of regional climate and actually a cooling influence. The other factor that is a cooling is aerosols. Their effects are not well understood and not represented in the global scale models, and agricultural aerosols are not represented at all in the Central Valley. The other factor not in the model is the snow albedo feedback, which is an amplifying effect on warming wherein the loss of snow itself creates warming, and in the course-scale models, there is no snow. So, we know that course-scale global climate models do not include a lot of the factors and influence that influence

regional scale climate, and the models are very, very coarse and they do not really adequately resolve the regional scale climate processes.

Dr. Duffy presented an observational study done by Drs. Bonfils and Lobell, said they looked at historical observations of temperature in California and they clearly showed for the first time that irrigation has had a significant influence on climate in California. The influence is a cooling in daytime in summer. This is part of the explanation of why, in looking on a statewide basis, we do not see any warming in summer in daytime; due to aerosols and irrigation. Irrigation exerts a cooling influence because if you wet the surface, there is more evaporation and that causes cooling. And this effect is strongest in the daytime and in summer due to irrigation. He presented model simulations that show irrigation can have a significant local cooling influence, temperature change due to a simplified representation of irrigation in a climate model, the August mean temperature, which shows keeping a surface wet locally cools the surface by degrees, which is a lot.

The other factor which he believes has a cooling influence on summer and daytime is the increased sea breeze, which is a consequence of global warming because it results from more rapid warming in the inland than coastal regions and is a consequence of the system being out of equilibrium or in a warming transition phase. The mechanism is when the temperature gradient increases, the sea breeze should increase and he said there is some evidence in the observations that this is happening. One of the things about this is that it is hard to imagine how this driver of climate will evolve as climate change proceeds.

Dr. Duffy said the other issue that needs more attention and something that will help us understand better is looking at other regions and reviewing those temperature trends. There is less warming in daytime, irrigation, aerosols and increased sea breeze are a cooling influence during the day. If there were an increase in low cloud it would be a cooling influence during the day and a warming influence at night. He said there was a paper which looked at the four days after 9-11 when there was no commercial air travel, and researchers saw a significant change in the observed temperature range during those four days which documents an influence of aircraft contrails on regional scale climate.

Regarding why there is more warming in winter and spring, Dr. Duffy said the reasons are similar—there probably is in reality a snow albedo feedback which amplifies wintertime warming. Interesting is that even though there is more snow loss in winter, the mechanism is increased through reflection of sunlight, so it is stronger in spring because there is more sunlight. Irrigation, sea breeze and aerosols are summer influences, and these mechanisms will tend to act preferentially in summer and in daytime.

Regarding the future, Dr. Duffy said he thinks the 21st century will be simpler than the 20th century was. He presented a schematic representation of the effects of different forcings on California temperatures including CO₂, aerosols, irrigation, and sea breeze for the 20th and 21st centuries. He believed the warming influences should get stronger and the cooling influences should get weaker. Greenhouse gases are clearly going to accumulate in the atmosphere and will become the dominant influence on climate; however, they are not right now. He said urbanization clearly is going to get stronger, aerosols are going to get weaker as air quality improves, he thinks there is no avoiding the conclusion that irrigation is also going to be weaker as a climate influence because we are not going to be able to use as much water in the Central Valley as historically done, the amount of agriculture land will decrease

and there will be water scarcity and irrigation will be practiced in a manner that uses less water.

Dr. Duffy presented predicted statewide trends and predicted temperature changes, stating there are 45 curves which represent 3 emission scenarios (scenarios for emissions of GHGs), they are based on different rates of population growth, economic growth, the use of coal, nuclear, etc. Half of the spread is due to the different scenarios and for half of any given scenario, the models do not agree because none of them are perfect. Also on the same scale, he presented the observed historical warming for California. The message is that, although there is a lot of uncertainty in future warming, even at the low end of the range it will be much more than we have already seen according to the models.

The other issue for air quality is temperature extremes which have many societal implications, such as air quality, human health impacts, implications on energy demand and he presented information from a study done for the Energy Commission. The picture in the slide illustrates a projected increase in temperature extremes on a statewide basis, showing the maximum one-hour temperature during each year, which increases very rapidly. He said though, looking at temperature over one hour is probably not the best measure of extreme temperatures. However, the mean temperatures in California are going to increase much more rapidly than they already have and temperature extremes will also increase, which has significant impacts on air quality particularly ozone.

In parting, Dr. Duffy said historical winter and spring warming in California seems to be too rapid to be entirely natural. In local regions like the Bay area, multiple factors have influenced temperatures. Irrigation, aerosols, increased sea breeze have probably slowed summer daytime warming in California, winter warming seems to be more rapid than can be explained by greenhouse gasses alone, and the 21st century may be less complicated than the 20th century was, and it will be warmer.

Dr. Duffy said what is needed and useful would be to look one at a time at the effects of these different factors that influence climate, such as doing careful simulations just of the effects of irrigation on climate, just on aerosol, just on greenhouse gasses, just urbanization, and what it will do is allow them to characterize the climate signatures that affect climate. Once we know what these should look like, then we can look for it in the observational record. Also what will help us understand what is going on in California is looking at neighboring regions. Also, when making future projections, we have used either very course models that include both the ocean and the atmosphere or fine resolution models that actually do not include an interactive ocean, and this is significant for the Bay Area because there are issues like the increase sea breeze effect, upwelling on the coast, which has not yet been adequately modeled.

Member Glueck questioned that, with all of the influences in the Bay Area, why are not some of the local studies being compared to areas outside the Bay Area. Dr. Duffy said the temperature records exist throughout most of the country, just by doing the comparison part one could learn a lot, but if the measurements have not been made, it's too late to do that. But just by doing the comparison part, we could learn a lot, and it does not require great resources to complete.

Member Glueck questioned whether or not reversals would be as dramatic if there were dramatic social or land use changes or reductions in the use of fossil fuels. Dr. Duffy said increases are dramatic if you compare them to the level of natural variability, but they have not been dramatic in the sense of having very noticeable impact. Globally, over the 20th century, temperatures warmed about one degree Fahrenheit, which is not noticeable. Regarding whether it would have dramatic societal impact, it would not; however, there might be impact in the future. Regarding whether or not we could reverse the impact, in principle, yes, but the problem is that the climate change we experience is the consequence of the sum total of global greenhouse gas emissions. So, if California or the entire United States cleans up its act, unless the rest of the world does, it does not help much. It does require cooperative action to address the problem. All of the scenarios, however, point to accelerated warming even assuming fairly significant action is taken on a global scale to reduce emissions.

Member Glueck questioned how much could we isolate out one particular region, and Dr. Duffy said you cannot; the climate change is the result of a sum total of global greenhouse gas emissions and this is why it is a tough problem. We can lead by example and we can prepare, and he believes California is doing a great job with both those things.

Member Altshuler said another way to say this is that pollution is very democratic. Dr. Duffy said this particular form of pollution is. The consequences of emitting are predominantly local, so if we dump mercury in our waters, it will not affect people in China.

Member Altshuler referred to irrigation, and said he can see temperatures on his front car bumper and when he drives through the Central Valley, he wondered if it was more of a crops issue than of irrigation. Driving through areas with grapes drops measurably by 3-4 degrees, but in grassland or dry areas, the temperature remains high. Dr. Duffy said his observation is probably correct; probably the reason for this is evaporative transportation. Crops are great at pulling water out of the ground and causing it to evaporate, which is the same mechanism whereby irrigation affects cooling. He said the study shown was very specific on comparing temperature trends and regions by degree of irrigation, and the more heavily irrigated the region is, the cooler the region. But he said he did not think irrigation is causing much in the Bay Area because we are not downwind from the Central Valley and we do not have a lot of irrigation here.

Member Altshuler discussed the temperature change and dryness in Blackhawk. Dr. Duffy agreed there was also much more traffic in Blackhawk and said the other thing he can sense is nighttime warming. He discussed his experiences of not cooling down at night like it used to and an example of the July 2006 heat wave.

Member Altshuler questioned if Dr. Duffy looked at the 1991 volcanic eruption, and Dr. Duffy said volcanic eruptions have a very significant, although short-lived, influence and they are factored into the models.

Member Altshuler referred to the drought situation, and he questioned if having less water to irrigate would cause more of a sea breeze, and Dr. Duffy said yes, the Central Valley would most likely warm up.

Member Holtzclaw questioned what Dr. Duffy was conceptually including for urbanization, given the number of factors such as the urban heat island, more concrete, less plants, more or less irrigation in suburban areas, more or less driving per capita, and ABAG compact modeling. Dr. Duffy said specifically as to what is in the models, he cannot provide a good answer because the simulations he does are global scale and he has never included urbanization. Speculatively, the two effects that are significant are a change in the surface color. Urban regions are darker, which is a warming influence, and the other factor is reduced evaporation; urban surfaces tend to be pavement and moisture from the soil cannot get through the pavement. More subtle effects like local emissions of heat from consumption of electricity are not in the simulation. He said there are a lot of activities in cities that directly creates heat and driving cars and running air conditioning is just two of them.

Member Holtzclaw referred to sea breezes, said there was an editorial writer who has since retired from the Chronicle and who wrote on weather 30-40 years ago. He explained the curious weather in the Bay Area as a 1 to 5 mile patch of colder sea waters right along the coast because of cooler deep currents that surface when they run into the continent. So the hot air with 60%-70% humidity hits that and it goes up as it cools up and this translates to our fog. So, part of global warming in some models might look at the ocean currents which may influence us here. Dr. Duffy agreed with this and said they refer to this as upwelling. The reason the water is notoriously cold off San Francisco is the upwelling of deeper, colder water to the surface and one of the things that drives the upwelling is the strong sea breeze, and the two things reinforce one another. Useful would be to simulate all of this with a model that includes both the ocean and atmosphere to model that phenomenon and this has not been done here. He said the fine resolution models used do not have interactive ocean and cannot simulate these feedbacks between the ocean and atmosphere which, for the Bay area, are significant. So, the questions being asked are exactly the ones they are least capable of answering.

Chair Kurucz referred to a previous data slide, stating there was not a trend in the daily summer maximum and questioned that as a whole, was there no trend or was there a slight cooling shown from this. Dr. Duffy said the gray regions have no statistically significant trends. The middle one is mostly gray, the right shows more cooling than anything else and he said his statement was to average the three pictures by eye, and it adds up to not much cooling. Also, there are other observational data sets besides these three and he just happened to use these three. He said he did not think cooling was likely to continue with the exception of sea breeze, which is hard to speculate how it will evolve. He believes the particulate and irrigation influences will get weaker, the greenhouse gas influences and urbanization will get stronger, but he is uncomfortable making this statement because it is not based on historical information, it is speculative, and only his opinion.

Chair Kurucz referred to contrails and asked if they are a strong correlation or factor, and Dr. Duffy said he did not believe it was a particularly strong factor. Chair Kurucz asked if it was in anyway an equilibrium with the fact that we often here that air travel is one of the biggest footprints that many of us have? Dr. Duffy said he did not know the answer.

Member Holtzclaw said intuitively, he would think that the CO₂ and other emissions that tend to increase temperature have much more momentum than aerosols which tend to dissolve a few hours later. Dr. Duffy said this is exactly right and one way to think of it is CO₂ basically accumulates in the atmosphere, it has a long lifetime and the concentration is

the sum total. Aerosols have short lifetimes and this is exactly why in the 20th century the climatic influence of greenhouse gases and aerosols are similar in magnitude. As time passes, this will change because we are reducing aerosols.

Chair Kurucz questioned whether what we see as a visible contrail was from the combustion of fuel creating water or was it decompression off of the wings, and Dr. Duffy said he believes it was from the combustion of fuels, but he was not absolutely sure.

Chair Kurucz, on behalf of the entire Committee, thanked Dr. Duffy for his presentation and presented him with Air District momentums.

5. Committee Member Comments/Other Business.

Member Altshuler said it was getting harder to dispose of fluorescent light bulbs; mercury is a pollutant and asked that the collection and/or recycling of CFL's be addressed legislatively.

Chair Kurucz reminded members that the next meeting would be held on August 4 at 9:30 a.m. Member Holtzclaw requested the October meeting be held on October 13th if possible or later in the week.

6. Time and Place of Next Meeting. 9:30 a.m., Monday, August 4, 2008, 939 Ellis Street, San Francisco, CA 94109.

7. Adjournment. 11:00 a.m.

Lisa Harper
Clerk of the Boards