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1 high end.

2 Dr. Lindzen: Look at the distribution of these dots.

3 [Dr. Lindzen handed the documents to Dr. Arking.]

4 Dr. Arking: Well, yes. This is not the same slope I am  
5 talking about.

6 Dr. Ramanathan: That is right.

7 Senator Gore: Dr. Ramanathan, do you want to respond?

8 Dr. Ramanathan: Yes. First of all, I think the slope  
9 they are talking about is a rate of increase of the trapping  
10 with sea surface temperature, and we estimated that slope  
11 after removing the upper end, and there is an enormous rise.  
12 If we had included it, it would have been much, much larger  
13 than anything computed by models.

14 Senator Gore: Let me shift gears now. We have heard  
15 about convection, and I want to see if I understand what you  
16 are saying, Dr. Lindzen, in the thrust of the argument that  
17 you have injected into this debate.

18 First of all, convection is the -- how would you define  
19 convection? When the temperature of the sea surface  
20 increases, the more water molecules escape as vapor, into the  
21 atmosphere and because they are hot, they rise and there is a  
22 movement of hot things to rise. The water vapor rises up to  
23 where it is cooled. Correct? All right.

24 Now, what you are saying essentially, Dr. Lindzen, as I  
25 understand it is that when the sea surface temperature

1 increases due to greenhouse gases, you do not dispute at all.  
2 the point that increasing carbon dioxide, methane,  
3 chlorofluorocarbons will cause an increase in temperature. It  
4 is just that you think it is a smaller increase in  
5 temperature. And you say that when that increase in  
6 temperature takes place, more water vapor will go into the  
7 boundary layer, the first 2 kilometers and then, you believe  
8 there may well be a convective mechanism by which the water  
9 vapor rises through the cloud column and detrains when it gets  
10 to the cooler, higher altitudes, in a pattern which results in  
11 an overall decrease in the amount of water vapor at those  
12 altitudes, with the even larger increase in water vapor at the  
13 lower altitudes, making for an increase in the total column,  
14 but because there is more at lower altitudes and less at  
15 higher altitudes, the overall effect of the Lindzen mechanism  
16 is cooling. Have I stated it correctly?

17 Dr. Lindzen: I have to say, that is about the longest  
18 sentence I have even heard as a academic.

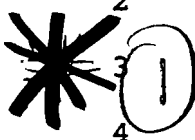
19 [Laughter.]

20 Senator Gore: Well, you will just have to forgive me.  
21 That is something the Senate is well known for.

22 Dr. Lindzen: I see.

23 Senator Gore: But aside from the length of the sentence,  
24 is it an accurate sentence?

25 Dr. Lindzen: Not quite, as best I can track it. First,

1 I must say, the subject is one that is -- you should excuse  
2 the expression -- in flux and so, for example, at this point,  
3  I am much more in agreement with Alan Betts than with my  
4 original proposition, but let me get to the point of this and  
5 it is the important and it has nothing to do with any theory.

6 Senator Gore: But I would like you to correct my  
7 sentence, if you could, because I want to understand what you  
8 are saying.

9 Dr. Lindzen: Okay. What I am trying to say is, the  
10 processes whereby the surface gets moisture into the lowest 2  
11 kilometers is very different from the process by which it gets  
12 moisture into the region above. The lowest part is separated  
13 from the region above by something called an inversion. There  
14 is literally a cap to that boundary there that tends to  
15 isolate it from the region above.

16 The region above is penetrated by these tall towers.  
17 Now, the interesting thing about these tall towers -- and that  
18 is the reason I am coming over to Alan's view -- if you just  
19 had these tall tower rising and detraining water vapor, the  
20 upper troposphere would be bone dry. You absolutely have to  
21 detrain liquid water and ice that would be carried by it, and  
22 it is that that supplies water vapor to the upper troposphere.

23 Senator Gore: Now say that again.

24 Dr. Lindzen: Okay. You have to have these towers.  
25 These towers go up. As they cool, water condenses, and it is

1 perfectly possible in principle that this condensed water just  
2 forms rain and, as a result, all you would be left with is  
3 saturated water vapor.

4 And what we are saying is, when we calculate the supply  
5 of moisture to the upper troposphere -- just of saturated  
6 water vapor, it is not enough to maintain any relative  
7 humidity at all. You would down to 2 percent and 5 percent.  
8 You observe about 20 percent, we will say, H2. We are saying,  
9 to maintain the observed relative humidity, you not only have  
10 to detrain water vapor, you have to detrain ice in forms which  
11 can be carried by the air and continuously re-evaporate into  
12 the environment, rather than falling as precipitation.

13 My point is, we do not know what determines how much  
14 comes out as ice, how much comes out of water, and how much  
15 rains.

16 Senator Gore: Okay. But let me come back to my effort  
17 to understand what you are saying. Leaving aside, for the  
18 moment, whether the moisture is in the form of ice or rain, or  
19 water vapor, the Lindzen mechanism, if I can call it that,  
20 describes a possible effect by which the increasing amounts of  
21 water vapor escaping from the sea surface create a more  
22 powerful convective column, which results in water in its  
23 various forms getting to the cooler altitudes and then pulling  
24 itself back down again, along with other water vapor that was  
25 already up there. Am I getting that wrong?

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1 Dr. Lindzen: I think you are touching on things that may  
2 be right or wrong. We do not know.

3 Senator Gore: No. But that is what you are saying, is  
4 it not?

5 Dr. Lindzen: No, no. That is not what I am saying.  
6 What I am saying is, we simply do not have a handle on whether  
7 clouds in a warmer environment will produce more ice crystals  
8 or less. We are suggesting that it is entirely plausible that  
9 in a warmer climate you will produce less ice and if you  
10 produce less ice, you will have a smaller source of water  
11 vapor aloft and you will, therefore, have a negative feedback.

12 Senator Gore: Well, let me ask a more specific question,  
13 because I had thought that what you were saying is that this  
14 mechanism will cause a drying of the upper troposphere.

15 Dr. Lindzen: I am saying the subsidence does produce  
16 drying, but you have a balance between the source of moisture  
17 there and the drying due to subsidence.

18 Senator Gore: Okay now, but wait a minute. Just hold on  
19 a second. The Lindzen mechanism, if it is proven to be  
20 correct, will produce a drying of the upper troposphere.  
21 Correct? Right or wrong?

22 Dr. Lindzen: This has been hypothesized by us.

23 Senator Gore: Us being?

24 Dr. Lindzen: Myself, student Di Jing Sun, others, that  
25 indeed, a warmer surface may very well lead to a reduced

1 humidity aloft.

2 Senator Gore: Well, just hold on just a second. I want  
3 to pin this down, because I want to make sure that I  
4 understand it. This is extremely important. It is extremely  
5 important. The Lindzen mechanism would, if correct, produce a  
6 drying of the upper troposphere. Correct?

7 Dr. Lindzen: Under increased surface warming, integrated  
8 over the globe. Yes.

9 Senator Gore: If the surface warms. Would you agree  
10 that it will?

11 Dr. Lindzen: You know, I do not want to, Senator, get  
12 into the bind of treating .1 degree the same as I treat 5.

13 Senator Gore: Okay. If the surface warms .1 degree,  
14 there will be extra water vapor, correct?

15 Dr. Lindzen: In the surface.

16 Senator Gore: All right. If the surface warms, the  
17 Lindzen mechanism would produce a drying of the upper  
18 troposphere. Correct.

19 Dr. Lindzen: Yes.

20 Senator Gore: Okay. Now, do we have any evidence that  
21 that is, in fact, occurring?

22 Dr. Lindzen: The answer is yes.

23 Senator Gore: Okay. What is it?

24 Dr. Lindzen: Okay. There is one, and all the evidence  
25 on this, on either side, is highly controversial.

1 Senator Gore: Well, before you disparage other people's  
2 evidence, could you give --

3  (2) Dr. Lindzen: No, no. But let me present this, because I  
4 am not disparaging others. I am disparaging my own. I am  
5 saying that there is a phenomenon that has been observed by  
6 Wallace Brooker and others, in the reconstruction of the  
7 climate 18,000 years ago, in the midst of the last glaciation,  
8 and this is a remarkable phenomenon, whereby their  
9 measurements show the surface --

10 Senator Gore: Excuse me. Excuse me, Dr. Lindzen. Just  
11 to keep this thing from flying off the edges -- it is very  
12 complex. Rather than looking at 18,000 years ago, do we have  
13 any evidence, observational evidence of the climate today that  
14 the upper troposphere is drying?

15 Dr. Lindzen: We have no evidence on either side for  
16 today. The virtue of 18,000 years ago is we know it was a  
17 long-term average and that is not available to us today.

18 Senator Gore: Okay. Now, does anybody else have  
19 evidence on this point? Dr. Betts?

20 Dr. Betts: Well, I would like to make some comments.  
21 Part of the confusion of the present discussion is that, if I  
22 understood Dr. Lindzen correctly, he has basically withdrawn  
23 the original "Lindzen hypothesis" you are referring to, which  
24 was that the primary source -- because he has recognized  
25 correctly that you cannot explain the present water balance in

1 the upper troposphere without large injections of ice. And  
2 the original argument that was presented a year or so ago, was  
3 based on these towers that you mentioned going to colder  
4 temperatures where what is called the saturation amount of  
5 water over ice is much lower. And that was the argument for  
6 those towers injecting less water if they go higher.

7 Senator Gore: Now, say that again. I am sorry, but that  
8 is one of the ways I can understand this.

9 Dr. Betts: Let me back up a little bit further and say  
10 that if the ocean's surface temperature warms, the equilibrium  
11 near the ocean surface shifts to warmer and moister air as a  
12 result of increased evaporation, increased surface  
13 temperature, and a complex balance of processes on a basin  
14 scale. As a result of that shift, the air that rises from  
15 near the surface and forms these thunderstorms in the tropics  
16 over the warm waters, will have higher outflow levels.

17 If the stratosphere cools, then that outflow equilibrium  
18 temperature can be colder and the amount of water vapor at the  
19 colder temperatures goes down rapidly with decreasing  
20 temperature. So if these towers did not inject ice into the  
21 upper troposphere, the air that they would inject would have  
22 had less water vapor in it, because it would be coming out  
23 higher, and there are some arguments because it was higher, it  
24 would be also be colder, because we expect the stratosphere to  
25 cool in these conditions.

1           However, the majority of the water at the highest levels  
2           that is put into the atmosphere by these deep thunderstorms is  
3           in the form of ice, and the amount that we believe is put in  
4           in the form of ice is also consistent qualitatively with the  
5           relative humidity, this 20, 30 percent that we observe in the  
6           upper atmosphere from, say, 12, 13 kilometers, down to about 6  
7           kilometers. So, Dr. Lindzen says he had now recognized that  
8           point, and the discussion now then centers back where we were  
9           earlier. It is what controls the equilibrium structure and  
10          whether that will shift.

11          ~~Senator Gore:~~ Okay. Well, hold on just a second. Are  
12          you withdrawing the original Lindzen hypothesis?

13          Dr. Lindzen: Oh, yes.

14          Senator Gore: Oh, you are. Okay.

15          Dr. Lindzen: Yes.

16          Senator Gore: All right. Now, I just want to clarify  
17          that for the record. I want to underline it. The original  
18          Lindzen hypothesis is formally, here today, at 11:45 a.m.,  
19          withdrawn. All right.

20          Dr. Lindzen: Well, in fact, it was much earlier that we  
21          withdrew it. There is a paper --

22          Senator Gore: Excuse me for not noticing it earlier.

23          Dr. Lindzen: Okay.

24          Dr. Rossow: I might mention a few pieces of evidence --  
25          at least one-and-three-quarter pieces, and I will tell you why

1 I say that. There is a data set from the SAGE satellite,  
2 which has been looked at in two ways. One is, this measure is  
3 essentially water vapor, outside of clouds, above about the  
4 middle of the atmosphere, as we refer to it -- altitude, say,  
5 7 kilometers and above. It indicates two things.

6 One is that the seasonal progression of water vapor  
7 changes tends to oppose what you might infer from this  
8 hypothesis, in that the warmer hemisphere, when it is in its  
9 warm phase, is moister aloft.

10 The other thing that is more interesting that it  
11 indicates, is that if you look at the spatial pattern of the  
12 water vapor, the lower stratosphere and upper troposphere have  
13 more water vapor in the areas where the convection is  
14 occurring. So it is a very suggestive relationship that the  
15 convection is actually injecting water at those levels.

16 Now, the other three-quarters piece of evidence, if you  
17 will, that some efforts have begun to try to look at the same  
18 thing, instead of using satellite data, using conventional  
19 attempts to measure water vapor in the upper atmosphere and  
20 comparing essentially the water vapor amount in warm years  
21 versus cold years. And I understand that the initial results  
22 seems to suggest the opposite, namely, that the warmer years  
23 were a little drier. However, when you show that to people  
24 who are experts in that type of instrumentation, they usually  
25 tell you that that is consistent with the errors those

1 instruments make.

2 So that is a partial piece of evidence in the sense that  
3 it points out that some of our sources of data need  
4 improvement.

5 For what it is worth, I should also mention what the  
6 models do. There are three models that I know of that include  
7 the particular processes that Dr. Lindzen has proposed are  
8 important to the story. And when you isolate in those models,  
9 the effect of the convection on upper atmospheric water vapor,  
10 it shows drying.

11 However, there are other processes in those models. And  
12 the net effect always seems to be a moistening.

13 Senator Gore: A paper, a letter to Nature dated  
14 February 7, 1991 by Rind and others states that new satellite-  
15 generated water vapor data shows that increased convection  
16 leads to increased water vapor above 500 millibars. What is  
17 500 millibars?

18 Mr. Rossow: About 5 kilometers. That is the data I was  
19 referring to.

20 Senator Gore: 5, 5.5 kilometers. That increased water  
21 vapor above 5.5 kilometers in approximate quantitative  
22 agreement with results from current climate models.

23 The same conclusion is reached by comparing the tropical,  
24 western, and eastern Pacific regions. Thus, we conclude that  
25 the water vapor feedback is not overestimated in models and