DR. TANS: THE TITLE IS A LITTLE BIT TOO OVERARCHING FOR WHAT I WILL BE ABLE TO TALK ABOUT. I WILL ONLY COVER A FEW ASPECTS THAT ARE REVEALED BY THE CO2 RECORDS, THE ONES THAT I HAVE TIME TO TALK ABOUT. THERE ARE, REALLY, TWO ASPECTS THAT I WILL COVER: ONE IS THE CUMULATIVE RISE IN CO2, AND WHAT WE CAN LEARN FROM THAT, SO REALLY THE OVERALL RECORD; AND SECONDLY, I WILL BE TALKING ABOUT SHORT-TERM VARIABILITY IN THE RATE OF INCREASE OF CO2, ABOUT INTERANNUAL VARIATIONS, EVEN LEAVING OUT VARIATIONS

0102

ON THE TIME SCALE OF FIVE AND TEN YEARS. THE LATTER WILL BE REMOVED TO REVEAL SHORT TERM VARIATIONS ONLY.

Slide 2 HERE'S ANOTHER WAY TO LOOK AT THE ENTIRE RECORD. I START THE PLOT ON THE Y-AXIS AT 280 PPM, STANDING FOR, MORE OR LESS, THE PRE-INDUSTRIAL CONCENTRATION. YOU SEE THIS IS THE ENTIRE RECORD FROM MAUNA LOA. THE THICK CURVE GOING THROUGH THE SEASONAL CYCLE IS THE DE-SEASONALIZED GROWTH RATE OR INCREASE OF CO2; AND TO THE RIGHT IS THE GLOBAL RATE OF EMISSIONS DUE TO FOSSIL FUEL BURNING AND CEMENT PRODUCTION, AS TABULATED BY THE CDIAC, THE CARBON DIOXIDE INFORMATION AND ANALYSIS CENTER.

NOW, IF YOU USE A MODEL OF THE OCEANS, OF THE OCEAN UPTAKE OF ANTHROPOGENIC CO2, AND APPLY THAT TO THE FOSSIL FUEL EMISSIONS AS TABULATED BY THE CDIAC, WHAT YOU WOULD EXPECT IS THE CURVE IN THE RED, AND YOU CAN IMMEDIATELY SEE TWO DISCREPANCIES. FIRST OF ALL, WHEN DAVE KEELING STARTED THESE MEASUREMENTS IN '58, CO2 WAS SIGNIFICANTLY LARGER THAN WHAT ONE WOULD EXPECT FROM FOSSIL FUEL BURNING ALONE. SO, IN OTHER WORDS, THERE HAD TO HAVE BEEN A SOURCE OTHER THAN FOSSIL FUEL BURNING BEFORE HE STARTED HIS MEASUREMENTS. AND SECONDLY, THAT THE RATE OF RISE THAT YOU WOULD EXPECT

0103

FROM FOSSIL FUEL BURNING ALONE IS SLIGHTLY LARGER AT THE END THAN WHAT WE ACTUALLY SEE.

Slide 3 FIRST I NEED TO SAY SOMETHING ABOUT THE OCEAN MODEL THAT I'M USING. IT IS THE HAMBURG OCEAN CARBON CYCLE MODEL THAT WAS PUBLISHED BY MAIER-REIMER IN 1987, LONG AGO; IT IS A FULLY THREE-DIMENSIONAL MODEL OF OCEAN CIRCULATION AND UPTAKE OF CO2, INCLUDING OCEAN CHEMISTRY; WHAT HE DID WAS TO CHARACTERIZE THE RESPONSE OF HIS OCEAN MODEL

TO INCREASING ATMOSPHERIC CO2. HE DID THAT BY A PULSE RESPONSE (BLACK CURVE). HE INJECTED 100 BILLION TONS OF CARBON INTO A HYPOTHETICAL ATMOSPHERE ABOVE THE OCEAN, AND CALCULATED HOW THE OCEANS WERE TAKING UP THIS PULSE AS A FUNCTION OF TIME. WHAT YOU SEE IS THAT THE INITIAL RATE OF UPTAKE BY THE OCEAN IS FAIRLY RAPID AND SLOWS DOWN OVER TIME. THIS IS THE ACTUAL RESPONSE OF THE MODEL, BUT HE COULD FIT IT VERY WELL WITH A SUM OF FOUR EXPONENTIALS. AS A PHYSICAL PICTURE OF THAT, YOU COULD IMAGINE THAT THE OCEANS ACT SOMEWHAT LIKE A BUNCH OF SEPARATE RESERVOIRS WHICH ARE INCREASINGLY LARGER AND HAVE INCREASINGLY SLOWER RESPONSE TIMES. INITIALLY THE RATE OF UPTAKE IS RAPID, MOSTLY BEING DONE BY THE SURFACE RESERVOIRS, WHICH HAVE A SMALL VOLUME, WITH AN EXPONENTIAL TIME

CONSTANT OF 1.9 YEARS; GRADUALLY, THOUGH, AS THAT PORTION OF THE UPTAKE GETS SATURATED, THE OTHER RESERVOIRS, THE LARGER ONES, WITH LONGER RESPONSE TIMES TAKE OVER AND DETERMINE THE TIME CONSTANT OF UPTAKE. SO AS TIME PROCEEDS, THE UPTAKE BECOMES SLOWER AND SLOWER. THERE IS ACTUALLY, ALSO, A PORTION OF THE CO2 EMISSIONS THAT IN THIS MODEL NEVER GETS DISSOLVED IN THE OCEAN; IT STAYS IN THE ATMOSPHERE FOREVER. THAT'S BECAUSE THE EROSION AND SEDIMENTATION CYCLE OF THE SEDIMENTS IS NOT INCLUDED IN THIS VERSION OF THE MODEL.

THE RED CURVE IS FROM ANOTHER INDEPENDENT OCEAN MODEL BY SARMIENTO, ET AL, PUBLISHED IN 1992. IT HAS ALMOST THE SAME PULSE RESPONSE. THESE RESPONSE CURVES ARE NOT VERY MODEL DEPENDENT.

Slide 4 I NEED ONE MORE PIECE OF INFORMATION, AND THAT IS A RECENT HIGH RESOLUTION ICE CORE RECORD GATHERED AT LAW DOME, NEAR THE COAST OF ANTARCTICA; IT SHOWS YOU THE CO2 LEVEL FOR THE LAST THOUSAND YEARS. ONE CAN SEE THE PRE-INDUSTRIAL LEVEL WHICH I DEFINE ACTUALLY AS 282 PPM, BUT YOU CAN ALSO SEE THE LITTLE ICE AGE, THE PERIOD BETWEEN 1600 AND 1800 WHERE CO2 IS A FEW PPM LOWER, PERHAPS 5 OR SO, THEN IT STARTS TO GO BACK UP, AND THE MODERN RISE REALLY STARTS IN, LET'S SAY, 1850.

WHEN YOU COMBINE THE MAUNA LOA RECORD, WHICH IS THE RED CURVE AT THE END, WITH THIS ICE CORE CO2 RECORD, AND YOU USE THE MAIER-REIMER OCEAN MODEL, THEN

YOU CAN ACTUALLY ATTRIBUTE WHERE THE CO2 HAS GONE. Slide 5 FIRST THE RED CURVE. THEY ARE CO2 EMISSIONS AS TABULATED BY CDIAC. THE CUMULATIVE EMISSIONS ARE ARE NOW AT 331, PLUS OR MINUS 25. THIS IS THE CDIAC'S OWN ESTIMATE OF CUMULATIVE EMISSIONS SINCE THE START OF THE INDUSTRIAL ERA, TAKEN TO BE 1850.

THEN THERE'S THE ATMOSPHERIC INCREASE (BLACK) AS MEASURED BOTH BY THE MAUNA LOA RECORD AND THE ICE CORE RECORD GOING BACK TO 1000 AD. THE BLUE CURVE IS WHAT THE OCEAN MODEL PREDICTS WHAT THE UPTAKE IN THE OCEAN SHOULD HAVE BEEN, WITH THE ATMOSPHERIC INCREASE AS RECORDED. THE OCEAN MODEL YIELDS TOTAL EMISSIONS IN THE ATMOSPHERE, POSITIVE OR NEGATIVE, NECESSARY TO EXACTLY MATCH THE RECORDED ATMOSPHERIC INCREASE. TERRESTRIAL EMISSIONS WERE PLAYING AN IMPORTANT ROLE IN THE 19TH CENTURY. IT WAS ONLY IN 1940 THAT FOSSIL FUEL BURNING OVERTOOK TERRESTRIAL EMISSIONS. THE MODEL PREDICTS THE OCEAN INCREASE AS SHOWN IN THE BLUE CURVE. THERE IS ONE DATA POINT THERE, AND IT REPRESENTS A SUMMARY BY CHRIS SABINE AND COLLEAGUES OF DECADES OF OCEAN MEASUREMENTS, NORMALIZED TO 1994 AND PUBLISHED IN 2004. IT SUMMARIZES THE MEASURED CUMULATIVE

0106

UPTAKE OF ANTHROPOGENIC CO2 THROUGH THE YEAR 1994, AND THAT'S THE ONE DATA POINT THERE; THE MAIER-REIMER MODEL ACTUALLY GOES THROUGH THIS DATA POINT ALMOST EXACTLY, WITH OF COURSE A LITTLE BIT OF LUCK. THE MODEL, PUBLISHED IN 1987, WAS A PREDICTION. IT IS ENCOURAGING THAT THIS OCEAN MODEL IS NOT TOTALLY FANTASY, AND I WILL USE IT.

NOW, WHAT YOU CAN SEE, BOTH FROM THE CURVES, AND FROM THE NUMBERS AT THE TOP, THAT WHEN YOU EXTRAPOLATE THE OCEAN UPTAKE BEYOND 1994 THROUGH THIS OCEAN MODEL, THEN YOU WOULD EXPECT THAT THE OCEANS BY NOW HAVE TAKEN UP ALMOST 150 BILLION TONS OF CARBON. IF YOU ADD UP THE NUMBERS, YOU SEE THAT, WITHIN ERROR, THE TERRESTRIAL BIOSPHERE PLAYS NO SIGNIFICANT ROLE. YOU CAN EXPLAIN THIS AS THE SUM OF ATMOSPHERIC AND THE OCEANIC INCREASES EQUALING, WITHIN ERROR, TOTAL FOSSIL FUEL EMISSIONS. HOWEVER, IF WE WANT TO MATCH THE ATMOSPHERIC RECORD EXACTLY, WE NEED SOMETHING ELSE BESIDES FUEL BURNING TO EXACTLY FOLLOW THE INCREASE RATE IN

THE ATMOSPHERE. THIS "SOMETHING ELSE" IS NET CHANGES IN THE TERRESTRIAL BIOSPHERE, PAINTED IN GREEN. SO THAT'S BASICALLY WHAT IS NEEDED TO CLOSE THE MASS BALANCE, TO CLOSE THE ACCOUNTING BOOKS EXACTLY, IF WE BELIEVE THE ATMOSPHERIC RECORD IS INDEED 100 PERCENT CORRECT AND WE BELIEVE THE FOSSIL FUEL EMISSIONS ARE EXACTLY AS COMPILED BY THE CDIAC. TO CLOSE THE BOOKS, WE SEE FROM

0107

THE TIME HISTORY OF CUMULATIVE EMISSIONS THAT THE NET EMISSIONS WERE POSITIVE IN THE 19TH CENTURY UNTIL ABOUT 1940, AND THEN BECAME NEGATIVE. WE FIND THAT NET TERRESTRIAL UPTAKE SINCE THEN HAS HAS BEEN ABOUT 0.3 BILLION TONS OF CARBON PER YEAR ON AVERAGE. THAT IS NOT VERY MUCH. WE SHOULD REMEMBER THAT THIS IS TOTAL NET TERRESTRIAL UPTAKE. IF THERE IS A SOURCE, SAY, MOSTLY FROM TROPICAL DEFORESTATION OF 1 AND A HALF BILLION TONS OF CARBON PER YEAR, GLOBAL NET UPTAKE IS STILL 0.3. THAT MEANS THE TOTAL UPTAKE OUTSIDE OF THE TROPICS, OR MAYBE EVEN IN THE TROPICS BUT NOT ACCOUNTED FOR, TOTALS THAT ONE AND A HALF PLUS 0.3, SO THERE IS 1.8 TERRESTRIAL UPTAKE SOMEWHERE.

Slide 6 I'M NOT SURE I'LL HAVE ENOUGH TIME, BUT THERE'S ANOTHER ARGUMENT BASED ON ISOTOPIC RATIOS, INDEPENDENT OF THIS MASS BALANCE ARGUMENT, THAT POINTS TO FUEL BURNING. IF YOU IMAGINE THAT YOU ARE FROM MARS AND YOU DON'T KNOW ANYTHING OR YOU DON'T WANT TO ACKNOWLEDGE THAT FOSSIL FUEL BURNING HAS SOMETHING TO DO WITH INCREASING CO_2, BUT YOU ARE ABLE TO MEASURE WHAT IS GOING ON IN THE ATMOSPHERE AND THE OCEANS, WHAT COULD YOU CONCLUDE FROM THOSE MEASUREMENTS?

WELL, THERE ARE SEVERAL ISOTOPIC RATIOS THAT CAN HELP YOU DRAW CONCLUSIONS ABOUT WHAT'S GOING ON, AFTER

0108

YOU HAVE MEASURED THE INCREASE OF CO_2 IN THE ATMOSPHERE. FIRST OF ALL, THIS ISOTOPIC RATIO, THE RATIO OF C-13 TO C-12, IS ABOUT 1 PERCENT. MOPE PRECISELY, 1.1 PERCENT OF ALL CARBON ON THE SURFACE OF THE EARTH IS ACTUALLY THE ISOTOPE C-13; THE OTHER 99 OR 98.9 PERCENT IS C-12. THOSE ARE THE RATIOS IN THAT MIDDLE COLUMN. THESE ARE THE RATIOS THAT ARE OBSERVED TYPICALLY IN THE VARIOUS RESERVOIRS. IN THE ATMOSPHERE, THE ABUNDANCE OF C-13

IS 1.1147% OF THAT OF C-12; IN THE OCEANS, OR RATHER WHAT COMES OUT OF THE OCEANS AND JOINS THE ATMOSPHERIC RESERVOIR, HAS THE SAME RATIO. THE TERRESTRIAL BIOSPHERE IS A LITTLE BIT DEPLETED IN C-13. COAL, OIL, AND NATURAL GAS ARE DEPLETED FURTHER. OVERALL THE AGGREGATE OF THE FOSSIL FUELS IS MORE DEPLETED IN CARBON-13 THAN, BUT STILL QUITE SIMILAR TO, THE TERRESTRIAL BIOSPHERE -- THERE'S A GOOD EXPLANATION FOR THAT -- BUT THE SMALL DIFFERENCE IS NOT HELPFUL FOR US TO DISTINGUISH BETWEEN THOSE TWO SOURCE TYPES. WE CAN REALLY ONLY DISTINGUISH, WITH C-13 ALONE, BETWEEN TERRESTRIAL OR FOSSIL SOURCES ON THE ONE HAND AND OCEANIC SOURCES ON THE OTHER. THAT'S WHAT WE CAN DO AT THIS POINT. HOWEVER, THERE IS ALSO C-14. THE FOSSIL FUELS ARE THE ONLY RESERVOIR FROM WHICH CO2 CAN BE PRODUCED THAT ENTERS THE ATMOSPHERE WITHOUT ANY C-14 IN IT; WHEREAS, THE OTHER RESERVOIRS HAVE PRETTY MUCH THE SAME C-14 TO TOTAL CARBON RATIO AS THE ATMOSPHERE.

Slide 7 WHAT DO WE SEE? THIS IS A TIME HISTORY

0109

FROM THREE DIFFERENT RECORDS OF WHAT HAPPENED TO C-13 IN THE ATMOSPHERE OVER THE LAST 250 YEARS. WE SEE THAT THE ATMOSPHERE IN PRE-INDUSTRIAL TIMES WAS MINUS 6 AND A HALF PER MIL, AND IT BECAME LOWER. NOW, IF YOU SEE THE INCREASE OF CO2 IN THE ATMOSPHERE AND YOU WANT TO POSTULATE THAT IT COMES FROM THE OCEANS, YOU HAVE A CONTRADICTION. AN OCEANIC SOURCE WOULD NOT HAVE CHANGED THE 13C/12C RATIO IN THE ATMOSPHERE. WHAT COMES OUT OF THE OCEAN HAS THE SAME ISOTOPE RATIO AS WHAT'S ALREADY THERE. AT THIS POINT WE KNOW THE SOURCE TO BE EITHER THE TERRESTRIAL BIOSPHERE OR SOME OLD SOURCE.

I DON'T HAVE A SLIDE OF C-14. IT'S MORE COMPLICATED BECAUSE THE 14C/C RATIO OF THE ATMOSPHERE WAS MESSED UP, IF YOU WILL, BY NUCLEAR TESTING, UNTIL THE TEST BAN TREATY IN LATE 1962, SO IT IS A MORE DIFFICULT RECORD TO READ. BUT IF YOU READ IT CAREFULLY AND YOU ACCOUNT FOR NUCLEAR TESTING, YOU CAN ALSO DEMONSTRATE THAT WHAT WE SEE NOW, THE BUILDUP OF CO2, IS CAUSED BY A SOURCE OF CARBON THAT IS VERY OLD. SO NOW WE KNOW IT CANNOT BE THE OCEANS, AND THE SOURCE HAS TO BE VERY OLD.

IN ADDITION TO THAT, THERE IS ANOTHER PIECE OF EVIDENCE. ALTHOUGH THE WAY I'M TALKING ABOUT IT IS STILL QUALITATIVE, IT IS THE CONCENTRATION OF CO2 IN

0110

THE NORTHERN HEMISPHERE BEING HIGHER THAN THE SOUTHERN HEMISPHERE. IT TELLS YOU THAT THE EXTRA CO2 COMES FROM THE NORTHERN HEMISPHERE PRIMARILY. AND THE DIFFERENCE BETWEEN THE TWO HEMISPHERES HAS INCREASED OVER TIME. SO YOU'RE LOOKING AT AN INCREASING SOURCE OF CARBON PRIMARILY IN THE NORTHERN HEMISPHERE THAT IS OLD. WELL, I THINK BY NOW WE HAVE TO HYPOTHESIZE THAT IT HAS TO BE FOSSIL FUELS.

Slide 8 ONE MORE LOOK AT THE OVERALL RECORD. THE BLACK CURVE IS WHAT IS REQUIRED FOR THE TOTAL NET SOURCE, BOTH FROM FOSSIL FUEL BURNING AND THE TERRESTRIAL BIOSPHERE, TO EXACTLY MATCH THE CO2 WIGGLES THAT ARE SEEN AT HIGH RESOLUTION IN THE MAUNA LOA RECORD AND AT LOWER RESOLUTION IN THE ICE CORE.

THE RED CURVE IS WHAT WE THINK WE KNOW THE FOSSIL FUEL EMSSIONS TO BE FROM THE CDIAC INVENTORY. THE DIFFERENCES BETWEEN THE BLACK AND RED CURVES ARE THE NET TERRESTRIAL EMISSIONS DEPICTED AT THE BOTTOM.

Slide 9 I'LL SKIP THAT.

Slide 10 AT THIS POINT I REACH MY FIRST CONCLUSION: THE OBSERVED INCREASE IN ATMOSPHERIC CARBON DIOXIDE SINCE PRE-INDUSTRIAL TIMES IS ENTIRELY DUE TO HUMAN ACTIVITIES -- NOT MOSTLY -- BUT ENTIRELY. WE KNOW THAT EVEN THE NET TERRESTRIAL SINK

0111

IS UNDER GREAT HUMAN INFLUENCE. AND BESIDES THAT, IT IS ONLY A SMALL, QUITE SMALL, NET SOURCE COMPARED TO FOSSIL FUELS ALONE.

Slide 11 NOW I GO ON TO THE NEXT PART. LET'S TALK ABOUT INTERANNUAL VARIABILITY. FIRST, I WANT TO SHOW YOU OR DEMONSTRATE TO YOU THAT WHAT WE SEE AT MAUNA LOA IS REPRESENTATIVE OF THE GLOBE. IN BLACK IS THE SMOOTH CURVE FROM WHICH THE SEASONAL CYCLE HAS BEEN REMOVED, AND WE HAVE TAKEN THE TIME DERIVATIVE OF IT. IT IS THE GLOBAL RATE OF INCREASE WITH THE SEASONAL CYCLE REMOVED. WE DO THE SAME THING FOR MAUNA LOA (IN RED), LIMITED TO THE TIME PERIOD WE HAVE FOR THE GLOBAL RECORD SINCE 1980. THE LATTER IS BASED ON ABOUT 20 DIFFERENT MARINE SITES INITIALLY, AND THe NUMBER HAS SLOWLY GROWN OVER TIME. YOU SEE THERE IS NOT REALLY MUCH DIFFERENCE. MAUNA LOA GIVES, INDEED, A GOOD

REPRESENTATION OF THE GLOBAL GROWTH RATE. THAT'S ONE THING TO KEEP IN MIND.

Slide 12 ANOTHER POINT IS THIS: WHEN WE LOOK AT THE ISOTOPIC RECORD AS RECORDED WITH THE GLOBAL OBSERVING SYSTEM, WE SEE THAT THE WIGGLES, THE VARIATIONS IN THE CO2 GROWTH RATE SINCE ABOUT 1990 ARE ALMOST EXACTLY, BUT NOT ENTIRELY, MIRRORED, IN A NEGATIVE WAY, BY THE WIGGLES IN THE RATE OF CHANGE OF THE 13C/12C RATIO. A HIGHER RATE OF INCREASE OF CO2 CORRESPONDS TO A DECREASE OF 13C/12C. IF YOU LOOK AT THIS

0112

RELATIONSHIP CAREFULLY, YOU CAN SAY THIS HAS TO BE THE TERRESTRIAL BIOSPHERE. IT HAS THE ISOTOPIC SIGNATURE OF THE TERRESTRIAL BIOSPHERE. SO YOU SEE THE VARIABILITY AS RECORDED BY MAUNA LOA IS GLOBAL; AND SECONDLY, IT IS CAUSED PRIMARILY BY THE TERRESTRIAL BIOSPHERE RATHER THAN BY THE OCEANS.

Slide 13 NOW, WHAT I'M GOING TO USE IS THIS: HERE YOU SEE THE MOST RECENT PART OF THE MAUNA LOA RECORD. ABOUT FIVE YEARS OR SO IN THE RED, AND I HAVE REMOVED THE AVERAGE SEASONAL CYCLE FROM THAT, AND THEN WHAT IS LEFT IS THE UNDERLYING SLOW INCREASE, BUT THERE IS VARIATION FROM MONTH TO MONTH. THESE VARIATIONS ARE SIGNIFICANT, THESE DIFFERENCES BETWEEN SUCCESSIVE MONTHS. WE BELIEVE THESE NUMBERS ARE GOOD TO ABOUT 0.1 PPM, BASED ON ONGOING COMPARISONS BETWEEN INDEPENDENTLY DERIVED RECORDS, RECORDS DERIVED INDEPENDENTLY BY SCRIPPS AND BY NOAA. THE UNCERTAINTY IS ABOUT AS LARGE AS THE THICKNESS OF THE LINE. SOME PART OF THE VARIATIONS IN THE GROWTH RATE FROM MONTH TO MONTH, THE DE-SEASONALIZED GROWTH RATE, ARE CAUSED BY REAL CHANGES IN ATMOSPHERIC SOURCES OF CO2, AND SOME OF IT BY VARIATIONS IN AIR MASSES MOVING OR ARRIVING AT MAUNA LOA. YOU CAN HAVE ONE MONTH WITH MORE THAN THE AVERAGE NUMBER OF AIR MASSES COMING FROM THE NORTH OR THE SOUTH, AND THAT CAN

0113

GIVE RISE TO SLIGHT VARIATIONS OF THE TREND. I WILL USE THESE VARIATIONS, THE MONTH-TO-MONTH VARIATION. I CALL THEM THE GROWTH RATE, THE MONTHLY GROWTH RATE.

Slides 14-18 I HAVE TO SKIP THESE. THEY ARE JUST SOME SLIDES TO PROVE THAT MY METHOD WORKS. I HAVE NO TIME FOR THAT NOW.

Slide 19 WHAT I'M DOING IS, I USE THESE MONTH-TO-MONTH VARIATIONS (WITH THE 5-YEAR AVERAGE TREND

REMOVED), AND RELATE THEM TO MONTH-TO-MONTH ANOMALIES IN CLIMATE, IN THIS CASE TEMPERATURE. AND WHAT I'M LOOKING FOR IS THE RESPONSE, THE DELAYED RESPONSE OF THE CO2 GROWTH RATE ANOMALIES TO TEMPERATURE ANOMALIES. THE OVERALL RESULT IS IN THE BLACK CURVE. SO IF YOU HAVE A PARTICULARLY WARM MONTH, AN ANOMALOUSLY WARM MONTH, SAY IN JUNE OF SOME YEAR, THE CO2 GROWTH RATE GOES UP; BUT IN THE FOLLOWING MONTH, IN JULY, THE GROWTH RATE IS STILL HIGHER DUE TO THE PREVIOUS MONTH, AND ON AND ON. WE FIND THAT THERE IS A DELAYED RESPONSE TO A SINGLE MONTHLY MEAN TEMPERATURE ANOMALY. THE RESPONSE INITIALLY IS POSITIVE, A HIGHER GROWTH RATE FOR A HIGHER TEMPERATURE, AND THEN IT TAPERS OFF AND BECOMES NEGATIVE ABOUT A YEAR LATER. I THINK THIS HAS SOMETHING TO DO WITH THE NITROGEN CYCLE, THE AVAILABILITY OF NITROGEN TO PLANTS.

I BELIEVE THIS RESULT IS ROBUST BECAUSE WHEN

0114

I APPLY MY METHOD TO THE FIRST HALF OF THE RECORD ALONE, IT GIVES YOU THE LOWER (DASHED) CURVE; IF I APPLY THE ALGORITHM TO THE LAST HALF OF THE RECORD, YOU GET THE DOT-DOT-DASH RECORD THAT IS JUST ABOVE IT, WHICH BASICALLY GIVES THE SAME ANSWER.

Slide 20 IF YOU LOOK AT THE FLASK RECORDS, NOT AT MAUNA LOA BUT AT THE GLOBAL FLASK RECORD IN BLUE, IT MIMICS THE 2ND HALF OF THE MAUNA LOA RECORD; YOU GET THE RED CURVE IF YOU AVERAGE OVER MONTHS, WHEN YOU MAKE THREE-MONTHLY AVERAGES, DIVIDING EACH YEAR INTO FOUR DATA POINTS. IN OTHER WORDS, THE GROWTH RATE ANOMALIES IN THE FIRST THREE MONTHS, SECOND THREE MONTHS, ETCETERA. WE FIND THE SAME GENERAL CHARACTER OF THE RESPONSE.

Slide 21 ONE CAN DO THE SAME THING WITH PRECIPITATION ANOMALIES. NOW THE RESPONSE IS A DECREASE IN GROWTH RATE TO HIGH PRECIP, WHICH GRADUALLY TAPERS OFF OVER TIME, AND IT DOES NOT CHANGE SIGN A YEAR LATER.

Slide 22 NOW, IF I APPLY THESE TWO RELATIONSHIPS THAT I FOUND, IF YOU APPLY THEM TO TEMPERATURE AND PRECIPITATION ANOMALIES, YOU WOULD PREDICT WHAT IS DEPICTED IN THE RED CURVE. THIS IS WHAT THE INTERANNUAL VARIATIONS WOULD LOOK LIKE, AND ACTUALLY IT EXPLAINS 63 PERCENT OF THE OBSERVED VARIANCE (IN BLACK) OF THE INTERANNUAL GROWTH RATE.

THE UNEXPLAINED (RESIDUAL) VARIATIONS ARE AT

0115

THE BOTTOM, THE DIFFERENCE BETWEEN THE OBSERVED AND THE PREDICTED GROWTH RATE. WE CAN EXPLAIN TWO-THIRDS OF THE VARIANCE BY THESE SIMPLE CLIMATIC RELATIONSHIPS.

Slide 23   SO THE CONCLUSION IS WHAT I JUST MENTIONED. THE FACT THAT WE CAN EXPLAIN A GOOD CHUNK OF THE INTERANNUAL VARIABILITY IMPLIES THAT THE OBSERVED 5-YEAR AVERAGED GROWTH RATE VARIATIONS ARE SIGNIFICANT, NOT JUST "NOISE".