

# Houston talk – 5/19/07 – 64 SLIDES

## GLOBAL CLIMATE CHANGE – A GEOLOGIC PERSPECTIVE

### WHAT DO THE DATA TELL US

THANK YOU FOR THAT VERY KIND INTRODUCTION.

**SLIDE 1.** I COME TO THIS SUBJECT AS A STUDENT, AS MOST OF YOU DO. I ALSO COME WITH A PASSION FOR GEOSCIENCE PUBLIC OUTREACH WHICH GOES BACK 40 YEARS.

FIVE YEARS AGO I WAS INVOLVED WITH AGI AND WE STARTED SOME MAJOR PUBLIC OUTREACH INITIATIVES.

TWO PRODUCTS FROM AGI I WANT TO ALERT YOU TO. THE FIRST IS A FOUR-PART SERIES ON GEOLOGY, GEOLOGIC PROCESSES AND GEOLOGIC HISTORY. THE FINAL PRODUCT IS TITLED “THE FACES OF EARTH” HAS TAKEN FIVE YEARS, COST \$4.5 MILLION AND IS NOW COMPLETE. YOU WILL SEE IT ON DISCOVERY SCIENCE STARTING JULY 23.

AND A BOOK BY MICHAEL COLLIER ON MOUNTAINS. WHEN WE FIRST TALKED IT WAS TO BE A CHILDREN’S BOOK SERIES. WE’RE STILL WORKING ON THAT IDEA AT AGI, BUT MICHAEL’S EDITOR HAD OTHER IDEAS FOR THIS SERIES.

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THIS IS THE FIRST OF FIVE BOOKS ON GEOLOGIC PROCESSES ILLUSTRATED BY MICHAEL'S AERIAL PHOTOGRAPHS. I HIGHLY RECOMMEND IT.

I WANT TO ACKNOWLEDGE LEE GERHARD AND BILL POLLARD FOR IDEAS AND SUPPORT AND BOB RAYNOLDS AND CHARLIE BARTBERGER FOR CRITICISM AND JANET TYRRELL-EAD FOR THE ILLUSTRATIONS.

**SLIDE 2.** TODAY WE WILL SHOW DATA, SOME SOLID, AND SOME TO SPECULATE ON. I WILL TRY TO QUANTIFY CERTAIN ASPECTS OF WHAT WE KNOW ABOUT CLIMATE CHANGE.

WE WILL FOLLOW THIS OUTLINE. IT WILL TAKE ONE HOUR TO DO JUSTICE TO THIS SUBJECT BUT I WILL TRY TO DO IT IN 45 MINUTES. ALL WHO ARE INTERESTED WILL BE ABLE TO DOWNLOAD THIS TALK FROM THE THOMASSON PARTNER ASSOCIATES, INC. WEBSITE OR FROM THE SIPES HOUSTON CHAPTER WEBSITE. YOU CAN ALSO SEE A 200-PLUS ENTRY BIBLIOGRAPHY ON BOTH WEBSITES.

**SLIDE 3.** I CAN UNEQUIVOCALLY SAY THAT

- CONSERVING ENERGY AND REDUCING ALL UNNECESSARY EMISSIONS ARE IMPORTANT TO SUSTAINABLE ENVIRONMENTS AND ECONOMIES.

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- WE MUST DO EVERYTHING POSSIBLE TO PLAN FOR BOTH A WARMER AND A COLDER FUTURE.

**SLIDE 4.** WE WILL ADDRESS THREE HYPOTHESES. (1) THE CLIMATE IS CHANGING AND IS WARMER NOW THAN OVER THE PAST 250 YEARS, (2) THAT ANTHROPOGENIC EMISSIONS OF GREENHOUSE GASES ARE THE MOST SIGNIFICANT DRIVER OF CLIMATE CHANGE AND (3) THAT NATURAL PROCESSES ARE THE MOST SIGNIFICANT CLIMATE DRIVERS.

**SLIDE 5.** THIS SLIDE SHOWS TEMPERATURE AND CO<sub>2</sub> CURVES AND HAS BEEN USED IN THE DEBATE ON THE IMPACT OF ANTHROPOGENIC CO<sub>2</sub> ON TEMPERATURE. CLEARLY THERE IS A CLOSE CORRELATION FOR THE LAST 450,000 YEARS. IT WAS FEATURED PROMINENTLY IN THE MOVIE “INCONVENIENT TRUTH”. THERE CAN BE NO QUESTION THAT CO<sub>2</sub> AND TEMPERATURE ARE INTIMATELY LINKED. BUT HOW ARE THEY LINKED? THAT IS THE QUESTION WE NEED TO ANSWER.

**SLIDE 6.** THIS SLIDE SHOWS THE GLOBAL CLIMATE SYSTEM. THE THIN GREEN ARROWS DESCRIBE PROCESSES AND INTERACTIONS. THE BOLD RED ARROWS SHOW ASPECTS THAT MAY CHANGE THROUGH TIME. FOR INSTANCE THERE ARE CONSTANT CHANGES IN THE AMOUNT OF SOLAR ENERGY HITTING THE EARTH – CHANGES IN THE ATMOSPHERIC COMPOSITION AND CIRCULATION

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AND CHANGES IN THE HYDROLOGIC CYCLE. SIMILARLY THERE ARE CHANGES IN OCEAN CIRCULATION. THE GLOBAL CLIMATE IS A NON-LINEAR, DYNAMIC AND VERY COMPLICATED SYSTEM.

**SLIDE 7.** THIS SLIDE IS FROM THE IPCC 2001 REPORT AND SHOWS ONE INTERPRETATION OF THE EARTH'S ENERGY BALANCE, EXPRESSED IN WATTS PER SQUARE METER [ $\text{Wm}^{-2}$ ]. THIS CHART WILL CHANGE AS WE LEARN MORE BUT IT WILL SUFFICE FOR NOW. NOTE THERE ARE APPROXIMATELY 342 [ $\text{Wm}^{-2}$ ] COMING FROM THE SUN AS SHORT WAVE RADIATION AND ONLY 107 [ $\text{Wm}^{-2}$ ] REFLECTED DIRECTLY BACK. ANOTHER 235 [ $\text{Wm}^{-2}$ ] EVENTUALLY GOES OUT AS LONG WAVE RADIATION, ADDING UP TO THE SAME 342 [ $\text{Wm}^{-2}$ ]. THE LOOP SHOWN IN THE LOWER LEFT SHOWS HOW THE GREENHOUSE GASES, MOSTLY WATER VAPOR, KEEP OUR PLANET AT AN AVERAGE 15° C INSTEAD OF A -18° C.

**SLIDE 8.** MAJOR DRIVERS OF CLIMATE CHANGE ARE SHOWN HERE. THESE INCLUDE THE MILANKOVITCH CYCLES. THERE ARE ALSO ATMOSPHERIC CAUSES AND TECTONIC CAUSES.

THE ECCENTRICITY CYCLE IS VERY POWERFUL AT 100,00 YEARS. THE TILT OF THE EARTH'S AXIS VARIES BETWEEN 22 AND 24 DEGREES EVERY 41,000 YEARS. THE EARTH WOBLES ON ITS AXIS CLOSER AND FARTHER FROM THE SUN OVER THE SPAN OF A 25,800 YEAR CYCLE.

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WE WILL DISCUSS ALL THESE OTHER IMPORTANT CHANGES AS WELL.

**SLIDE 9.** THIS SHOWS CLIMATE CHANGE FOR THE LAST, APPROXIMATELY, 550 MILLION YEARS WITH GLACIATIONS OCCURRING IN THE LATE ORDOVICIAN AND EARLY SILURIAN AT 450 MILLION YEARS, ANOTHER GLACIAL PERIOD IN LATE CARBONIFEROUS AND EARLY PERMIAN CENTERED AROUND 300 MILLION YEARS. AND THE LATEST GLACIAL ERA, STARTING ABOUT 50 MILLION YEARS AGO. HOW DO WE KNOW ALL OF THIS? THIS IS DONE WITH VARIOUS PROXIES. FOR INSTANCE THIS SLIDE IS BASED ON THE RATIO OF OXYGEN EIGHTEEN [ $^{18}\text{O}$ ], TO OXYGEN SIXTEEN [ $^{16}\text{O}$ ] MEASURED IN PARTS PER THOUSAND. DEEP SEA CORES PROVIDE MUCH OF THESE TEMPERATURE DATA. DEUTERIUM [ $^2\text{H}$ ], WHICH IS AN ISOTOPE OF HYDROGEN, IS A GOOD TEMPERATURE INDICATOR IN ICE. CARBON FOURTEEN [ $^{14}\text{C}$ ], BERYLLIUM TEN [ $^{10}\text{Be}$ ], AND ARGON FORTY [ $^{40}\text{Ar}$ ] ARE ALSO IMPORTANT PROXIES.

**SLIDE 10.** THIS SLIDE SHOWS THE CLIMATE RECORD FOR THE LAST 4 MILLION YEARS. NOTE FROM 3 TO 1 MILLION YEARS AGO THE 41,000 YEAR MILANKOVITCH CYCLE DOMINATED AND FOR THE LAST ONE MILLION YEARS THE 100,000YEAR CYCLE HAS DOMINATED. TO MY KNOWLEDGE, NO ONE KNOWS WHY. THESE DATA ARE TAKEN FROM ICE IN ANTARCTICA AND FROM OCEAN DRILLING SITES IN THE EASTERN EQUATORIAL ATLANTIC.

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**SLIDE 11.** THESE DATA FROM AN ICE CORE FROM GREENLAND DEMONSTRATE THAT WHETHER IT'S HEATING OR COOLING DEPENDS ON YOUR PERSPECTIVE. IT HAS BEEN HEATING OVER THE LAST 17,000 YEARS, BUT COOLING FOR THE LAST 10,000 YEARS AND ESPECIALLY THE LAST 2000 YEARS. BUT IT HAS BEEN HEATING FOR THE LAST 700 YEARS AND ALSO THE LAST 100 YEARS. IT REALLY DOES DEPEND ON THE TIME FRAME YOU CHOOSE.

**SLIDE 12.** WELL, LET'S STICK WITH TEMPERATURE FOR A WHILE LONGER. THIS SLIDE SHOWS THE TEMPERATURE OF THE SARGASSO SEA BASED ON OXYGEN<sup>18</sup> TO OXYGEN<sup>16</sup> RATIOS FROM A DEEP SEA SEDIMENT CORE. THIS IS ONE OF SEVERAL STUDIES OF THIS TYPE, WHICH SHOW OVER THE LAST 3,000 YEARS, SOMETHING CALLED THE ROMAN WARM EVENT ABOUT 2,500 YEARS AGO, THE MEDIEVAL CLIMATE OPTIMUM ABOUT 900 YEARS AGO AND THE LITTLE ICE AGE AT ITS MOST INTENSE ABOUT 300 YEARS AGO.

**SLIDE 13.** SO IT LOOKS LIKE THE SUN DOMINATES OUR CLIMATE – AND CERTAINLY IT DOES IN PART. BUT NOT SO FAST. THIS SLIDE SHOWS THE SUN SPOT CYCLES FOR THE PAST FOUR HUNDRED YEARS FOR WHICH WE HAVE RECORDS SUPERIMPOSED ON SOLAR IRRADIANCE. NOTE THE UNITS RANGING FROM 1363.5 WATTS PER SQUARE METER TO 1366.7 WATTS PER SQUARE METER. OVER THE LAST 300 YEARS, SOLAR IRRADIANCE HAS ONLY INCREASED 0.2% - NOT ENOUGH TO EXPLAIN THE MOST RECENT TEMPERATURE INCREASE.

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SO WHAT HAVE WE SAID: THE SUN HAS A BIG IMPACT ON EARTH TEMPERATURE BUT CURRENT IRRADIANCE IS NOT LARGE ENOUGH TO CAUSE THE CURRENT WARMING WE SEE.

**SLIDE 14.** THIS SLIDE SHOWS GLOBAL MEAN SURFACE TEMPERATURE OVER THE LAST 125 YEARS. THESE DATA ARE NOT PARTICULARLY ACCURATE, BUT THEY ARE ALL WE HAVE – TAKEN FROM STATIONS ALL OVER THE WORLD. THESE APPROXIMATE A 0.65°C, OR 1°F, INCREASE FROM 1900 TO 2005. THERE ARE TWO MAJOR PROBLEMS WITH THESE DATA. IN MANY AREAS IN RECENT YEARS CITIES HAVE GROWN AND ENCOMPASSED THE STATION. IN OTHER AREAS THEY WERE ALREADY IN CITIES. THERE ARE URBAN HEAT ANOMALIES WHICH CAN BE UP TO 3° C. THE OTHER PROBLEM IS THAT SOME ARE TAKEN CARELESSLY.

**SLIDE 15.** THIS SLIDE SHOWS THE APPROXIMATE 8000 WEATHER STATIONS AROUND THE WORLD. NOTE CONCENTRATION AREAS AND VERY SPARSE AREAS. THE LARGER RURAL AREAS, OCEANS AND ICE CAPS ARE NOT WELL REPRESENTED.

**SLIDE 16.** THIS SLIDE SHOWS MUCH MORE ACCURATE DATA TAKEN IN THE UNITED STATES. THEY SHOW APPROXIMATELY THE SAME INCREASE BUT NOTE THAT THE TEMPERATURES IN THE 1930S WERE AS HIGH AS THE HIGHLY TOUTED

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HOT 1998. NOTE ALSO THE GENERAL DECREASE SINCE 1998; HOWEVER, THE NUMBERS ARE JUST IN FOR 2006 AND IT HAS BOUNCED BACK UP.

IF ONE TOOK THE DATA FROM 1930 TO 1977 AND THEN PROJECTED IT – IT WOULD LOOK LIKE THE RED ARROW.

**SLIDE 17.** THIS 35 YEAR DOWNWARD TREND CAUSED A TIME MAGAZINE COVER STORY TO PREDICT A COMING ICE AGE – BECAUSE THAT’S WHAT MANY CLIMATOLOGISTS WERE PREDICTING.

**SLIDE 18.** WE WILL COME BACK TO TEMPERATURE VARIATIONS AND THEIR CAUSES. LET’S NOW LOOK AT TECTONIC CAUSES. OCEAN CURRENTS PLAY A BIG ROLE IN THE TEMPERATURE CHANGES AND THE FORMATION OF ICE CAPS. THIS SLIDE SHOWS FOUR SEPARATE CASES. IN THE LATE PROTEROZOIC GLACIATION OCCURRED. THIS WAS DUE TO BOTH POLAR CURRENTS AND A LAND MASS AT THE SOUTH POLE. IN THE EARLY DEVONIAN, 390 MILLION AND EARLY CARBONIFEROUS 335 MILLION YEARS AGO, THERE WERE EQUATORIAL CURRENTS AND NO GLACIATION. BY LATE CARBONIFEROUS 306 MILLION YEARS AGO POLAR CURRENTS AGAIN INITIATED GLACIATION WITH A LAND MASS AT THE POLE, MUCH LIKE TODAY.

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**SLIDE 19.** THIS IS THE SITUATION TODAY WITH POLAR CURRENTS AND A LAND MASS AT THE SOUTH POLE. WATER CURRENTS ARE DRIVEN BY WIND AND WIND IS DRIVEN BY EVAPORATION AND CONDENSATION. AIR PICKS UP WATER VAPOR FROM EVAPORATION IN THE TROPICS, WHERE IT'S HOT, HEADS NORTH WHERE IT COOLS, CONDENSES AND CAUSES PRECIPITATION (SNOW). THE POLAR ICE CAPS ARE FORMED BY THIS PRECIPITATION, THEN COOL DRY AIR HEADS BACK SOUTH, DRIVING THE OCEAN CURRENTS BACK TO THE SOUTH WHERE IT GOES THROUGH THE CYCLE AGAIN.

**SLIDE 20.** THIS SLIDE SHOWS THE ATMOSPHERIC COMPOSITION WITH NO WATER VAPOR. CO<sub>2</sub> IS 0.038 – THIRTY-EIGHT THOUSANDTHS OF 1%. YOU HAVE TO MENTALLY ADJUST THESE NUMBERS FOR AN AVERAGE OF ABOUT 2% WATER VAPOR NOT SHOWN HERE. BUT YOU CAN PUT CARBON DIOXIDE AND METHANE INTO PERSPECTIVE. THERE ARE TRACE GASES IN THE ATMOSPHERE.

**SLIDE 21.** THIS SLIDE SHOWS WORLDWIDE ESTIMATED SOURCES AND SINKS OF CARBON – THE CARBON CYCLE. MAN-MADE SOURCES ARE NOT INSIGNIFICANT AND APPROXIMATE 4.3% OF THE TOTAL CARBON RELEASED TO THE ATMOSPHERE. NOTE THE BIGGIES ARE OCEAN RELEASE AND UPTAKE BY THE OCEANS. ALSO BIOMASS RESPIRATION AND DECAY AND BIOMASS PHOTOSYNTHESIS ARE VERY IMPORTANT. THE ACTUAL INCREASE CAUSED BY THESE ANTHROPOGENIC SOURCES IS NOT WELL UNDERSTOOD, SINCE THE

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TOTAL INCREASE IN THE LAST HUNDRED YEARS IN THE ATMOSPHERE IS 100 PPM  
OR 0.0100%.

**SLIDE 22.** WATER VAPOR MAKES UP 95 TO 97% OF THE TOTAL GREENHOUSE GASES. ASSUMING 95% THE OTHER 5% IS COMPOSED OF NATURAL SOURCES THAT APPROXIMATE 4.6% AND ANTHROPOGENIC SOURCES THAT MAKE UP 0.4%, NOT A VERY SIGNIFICANT PERCENT OF THE TOTAL GREENHOUSE GASES.

**SLIDE 23.** CO<sub>2</sub> DATA FROM THE SIPLE ICE CORE FROM ANTARCTICA HAVE BEEN MERGED WITH THE MAUNA LOA, HAWAII DATA. THERE WAS AN 83 YEAR GAP SO THE SIPLE ICE CORE DATA WERE SHIFTED 83 YEARS FORWARD TO GIVE THE CURVE WHICH IS CURRENTLY RECOGNIZED BY MOST RESEARCHERS. THIS CURVE HAS BEEN CONSTRUCTED FROM 10,000 YEARS AGO TO THE PRESENT.

**SLIDE 24.** APPARENTLY NOT SO FAST ON CO<sub>2</sub> EITHER. ERNST-GEORG BECK HAS COMPILED DATA FROM SOME 175 PAPERS BY PREVIOUS WORKERS COVERING WELL THE PERIOD FROM 1812 TO 1961. IT SOUNDS AUTHENTIC. A TOTAL OF 90,000 MEASUREMENTS BY CHEMICAL METHODS ARE REFERENCED. THE SCIENTISTS REFERENCED ARE MOSTLY GERMAN AND FRENCH WITH TWO NOBEL PRIZE WINNERS, INCLUDING KROGH AND WARBURG.

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THIS IS COMPARED TO THE ICE CORE RECONSTRUCTION AND MAUNA LOA DATA AND SHOWS A DRAMATIC DIFFERENCE. NOTE THAT THERE IS A FAIRLY GOOD CORRELATION BETWEEN THE ICE CORE DATA AND BECK FROM 1870 TO 1930 – SOME SIXTY YEARS, AND AGAIN A GOOD CORRELATION IN THE 1950S.

**SLIDE 25.** THIS SLIDE SHOWS A MORE DETAILED PLOT. NOTE THE RISE STARTING IN 1935 WITH A PEAK IN 1942. THESE DATA HAVE A BROAD GEOGRAPHIC DISTRIBUTION INCLUDING EUROPE, USA, ATLANTIC, ALASKA, INDIA AND ANTARCTICA. THEY REFLECT 41 DIFFERENT SERIES OF MEASUREMENTS. THEY WERE REVIEWED AND HAD LITTLE LOCAL CONTAMINATION. NOTE THE LOGICAL INDEPENDENT SUPPORT BY SIX WORKERS FOR THIS CURVE. COULD THIS REFLECT WORLD WAR II? IT FITS TIME-WISE!

**SLIDE 26.** THIS SLIDE COMPARES THREE TEMPERATURE SERIES SHOWN HERE TO THE CO<sub>2</sub> DATA. NOTE TEMPERATURE GOING UP WELL BEFORE CO<sub>2</sub> GOES UP. SO WHAT HAVE WE SAID: THERE ARE TWO SETS OF CO<sub>2</sub> RECORDS THAT ARE VERY DIFFERENT. WHICH IS CORRECT? I DON'T KNOW. BUT I RECOMMEND THAT YOU GET BECK'S PAPER AND READ IT

**SLIDE 27.** THIS SLIDE SHOWS THE PHANEROZOIC TEMPERATURE ESTIMATES AGAIN. THE BLACK CURVE AND A SMOOTHED RED CURVE ARE TEMPERATURE

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BASED ON PROXIES - COMPARED TO PAST CO<sub>2</sub> ESTIMATES SHOWN IN GREEN.  
THEY MAY HAVE A RELATIONSHIP BUT IT IS NOT OBVIOUS.

**SLIDE 28.** NOW LET'S LOOK AT SOME POSSIBLE ATMOSPHERIC CAUSES. THIS SLIDE SHOWS THE MAJOR INCREASE IN CO<sub>2</sub> CORRELATING WITH TEMPERATURE USING THE VOSTOK ICE CORE PUBLISHED BY PETIT, ET AL. THIS BURST OF CO<sub>2</sub> CERTAINLY APPEARS TO BE MAN'S IMPRINT, AND I BELIEVE IT IS. I TOOK THIS SET OF CURVES APART CAREFULLY AND TEMPERATURE GOES UP BEFORE CO<sub>2</sub> IN EVERY CASE. PETIT, ET AL. REPORTS THE SAME RELATIONSHIP. WE WILL EXAMINE SOME OF THESE TERMINATIONS IN DETAIL, BUT WITHOUT KNOWING THAT TEMPERATURE RISES BEFORE CO<sub>2</sub> THIS CURVE COULD BE USED TO MISLEAD THE PUBLIC.

**SLIDE 29.** LET'S LOOK AT SOME PAST CO<sub>2</sub> TEMPERATURE RELATIONSHIPS. MONNIN, ET AL. STUDIED THE LAST GLACIAL TERMINATION IN THE VOSTOK ICE CORE. FISHER, ET AL. STUDIED THE LAST THREE TERMINATIONS AND SIEGENTHALER, ET AL. LOOKED BACK AT TERMINATIONS V, VI AND VII. THE GLACIAL TERMINATIONS ARE NUMBERED FROM I TO VII FROM YOUNGEST TO OLDEST. NOTE THE SHAPE OF THE CURVES WITH A VERY ABRUPT RISE IN TEMPERATURE AND CO<sub>2</sub> FOLLOWED BY A GRADUAL DECLINE INTO AN INTERGLACIAL.

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THERE IS A PROBLEM WITH USING ENCASED CO<sub>2</sub> FROM BUBBLES BECAUSE THE AIR IS ACTUALLY YOUNGER THAN THE ICE. THIS IS BECAUSE THE AIR IS CIRCULATING THROUGH THE SNOW AND FERN UNTIL THE FERN FINALLY SETS UP AS ICE DUE TO THE WEIGHT OF YOUNGER SNOW OVER IT. ALL THE WORKERS IN THIS FIELD HAVE DEVELOPED DENSIFICATION FACTORS WHICH THEY APPLY TO COMPENSATE FOR THIS. DEUTERIUM (AN ISOTOPE OF HYDROGEN) IN THE ICE AROUND THE BUBBLE IS USED AS A TEMPERATURE INDICATOR AND CAN BE CORRELATED WITH THE <sup>18</sup>O ISOTOPE DATA FROM DEEP SEA CORES TO GET THE CORRECT DATING AND TEMPERATURE. THE CO<sub>2</sub> IN THE AIR IS MUCH YOUNGER THAN THE DEUTERIUM DATED TO THE ORIGINAL SNOW LAYER; SO IN EACH CASE A “DENSIFICATION” FACTOR MUST BE CALCULATED.

THESE DATA ON THE LAST THREE GLACIAL TERMINATIONS ARE OBTAINED FROM THE TAYLOR DOME, VOSTOK AND BYRD ICE CORES FROM ANTARCTICA. WE WILL LOOK AT TERMINATION I IN MORE DETAIL.

**SLIDE 30.** THIS SLIDE SHOWS THE ANALYSIS FOR TERMINATION I AFTER THE DENSIFICATION FACTOR HAS BEEN APPLIED. THE MAXIMUM CO<sub>2</sub> CONCENTRATIONS ARE REACHED 600 TO 1000 YEARS AFTER THE BYRD CORE TEMPERATURE PEAKS.

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**SLIDE 31.** AT TERMINATION II, CO<sub>2</sub> REACHES ITS MAXIMUM 400 ± 200 YEARS LATER THAN THE TEMPERATURE INCREASE.

**SLIDE 32.** AT TERMINATION III THE MAJOR INCREASE IN CO<sub>2</sub> TENDS TO LAG TEMPERATURE BY 600 ± 200 YEARS.

**SLIDE 33.** ATMOSPHERIC CO<sub>2</sub> CONCENTRATIONS SHOW A SIMILAR INCREASE FOR ALL THREE TERMINATIONS, CONNECTED TO A CLIMATE DRIVEN NET TRANSFER OF CARBON FROM THE OCEAN TO THE ATMOSPHERE.

THE TIME LAG OF THE RISE IN CO<sub>2</sub> CONCENTRATIONS WITH RESPECT TO TEMPERATURE CHANGE IS ON THE ORDER OF 400 TO 1000 YEARS DURING ALL THREE GLACIAL-INTERGLACIAL TRANSITIONS.

A QUOTE FROM FISHER, ET AL.: “IN THE CASE OF RECENT ANTHROPOGENIC WARMING, THE EXTERNAL CLIMATE FORCING BY CO<sub>2</sub> EMISSIONS **LEADS** CLIMATE VARIATIONS, SO APPLYING THE CO<sub>2</sub>–CLIMATE RELATIONS SEEMS NOT TO BE STRAIGHTFORWARD.”

**SLIDE 34.** CAILLON ADDRESSED THIS DENSIFICATION PROBLEM AND SOLVES IT IN A UNIQUE WAY. HE USED CARBON DIOXIDE AND ARGON 40 [<sup>40</sup>Ar] FROM THE SAME AIR BUBBLES ACROSS TERMINATION III. ON THIS SLIDE YOU CAN SEE

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THE CORRELATION HE MADE BETWEEN  $^{40}\text{Ar}$  AND DEUTERIUM – A VERY GOOD ONE.

**SLIDE 35.** IN THIS SLIDE HE CORRELATES CARBON DIOXIDE IN BLACK WITH ARGON IN RED AND GETS AN 800-YEAR ADJUSTMENT SHOWN HERE. TEMPERATURE INCREASE PRECEDES  $\text{CO}_2$  INCREASE BY 800 YEARS.

**SLIDE 36.** CAILLON CONTENDS AND I THINK HE IS CORRECT THAT:

- THE USE OF A TEMPERATURE PROXY MEASURED IN AIR BUBBLES MAKES THE COMPARISON WITH OTHER PROPERTIES MORE ACCURATE
- THE INCREASE IN  $\text{CO}_2$  LAGS ANTARCTIC WARMING BY  $800 \pm 200$  YEARS
- “THIS CONFIRMS THAT  $\text{CO}_2$  IS NOT THE FORCING THAT INITIALLY DRIVES THE CLIMATIC SYSTEM DURING A DEGLACIATION.”
- HE GOES ON TO SAY, “THIS SEQUENCE OF EVENTS IS STILL IN FULL AGREEMENT WITH THE IDEA THAT  $\text{CO}_2$  PLAYS, THROUGH ITS GREENHOUSE EFFECT, A KEY ROLE ON AMPLIFYING THE INITIAL ORBITAL FORCING.”

ALL THE WORKERS, INCLUDING PETIT, ET AL., FISHER, ET AL., MONNIN, ET AL. CAILLON, ET AL. AND SIEGENTHALER, ET AL. GET AN AVERAGE OF AN 800 YEAR DELAY. HOWEVER, IT VARIES FROM 400 TO OVER 2000 YEARS.

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**SLIDE 37.** HERE IS ANOTHER WAY TO LOOK AT CO<sub>2</sub> AND TEMPERATURE.

INDERMUHLE, ET AL. TOOK THIS CURVE FROM PETIT, ET AL. AND RELATED CO<sub>2</sub> IN PARTS PER MILLION TO THE ACTUAL TEMPERATURE CHANGE GIVEN BY PETIT, ET AL. AT THE A4 TEMPERATURE INCREASE IT GOES CONSERVATIVELY FROM – 8.0 TO – 4.5 OR AN INCREASE OF 3.5°C AND THAT RELATES TO A LIBERALLY MEASURED CO<sub>2</sub> INCREASE OF APPROXIMATELY 26 PARTS PER MILLION. USING THAT RATIO THE INCREASE OF 100 PARTS PER MILLION OVER THE LAST 100 YEARS WOULD INDICATE WE SHOULD HAVE HAD A TEMPERATURE INCREASE OF 13.5°C, WHEN IN REALITY THE INCREASE HAS BEEN APPROXIMATELY 0.6°C. HOWEVER, WE DON'T KNOW WHAT THE REACTION TIME MIGHT BE, AND WE DON'T KNOW THAT IT IS DIRECTLY PROPORTIONAL. BUT IT IS ANOTHER LINE OF EVIDENCE SUGGESTING THAT CO<sub>2</sub> MAY NOT BE DRIVING THE CURRENT TEMPERATURE INCREASE.

**SLIDE 38.** REMEMBER THAT THE SUN'S ENERGY ARRIVES ON EARTH AS SHORT WAVE LENGTHS AND IS RADIATED BACK AS INFRARED LONG WAVE ENERGY. THESE LONG WAVE LENGTH RAYS ARE THE ONES THAT THE GREENHOUSE GASES ABSORB AND RE-EMIT. THIS SLIDE SHOWS THE ABSORBTIVITY OF WATER AND CO<sub>2</sub> BUT NOT TO SCALE. THIS IS AN IMPORTANT MEASUREMENT SINCE IT RELATES TO THE RELATIVE EFFECTIVENESS OF THESE TWO GREENHOUSE GASES. NOTE ESPECIALLY THE APPARENT GAP IN WATER

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VAPOR AT ABOUT 4 MICRONS WHICH IS FILLED BY CO<sub>2</sub>. MOST OF THE OTHER CO<sub>2</sub> IS COVERED BY WATER VAPOR. IS THIS GAP REAL?

**SLIDE 39.** NEEDLESS TO SAY, I AM NO THERMODYNAMICIST, BUT I CONSULTED WITH DR. JAY McGREW, WHO IS A PROFESSOR IN THE SUBJECT. HE SAYS WITH GREAT AUTHORITY THAT WATER VAPOR IS ACTIVE AT ALL WAVE LENGTHS – THERE ARE NO GAPS. THESE DATA FROM THE SMITHSONIAN ASTROPHYSICAL OBSERVATORY SHOW THAT WATER DOES GO THROUGH THE APPARENT 4 MICRON WAVE LENGTH “GAP” SHOWN ON THE PREVIOUS SLIDE. NOW CONSIDER THAT WATER IS 50 TIMES MORE ABUNDANT BECAUSE OF THE 20,000 PPM WATER VERSUS 380 PPM CO<sub>2</sub>. DR. McGREW BELIEVES YOU WILL COMPLETELY OVERWHELM THE CO<sub>2</sub>.

**SLIDE 40.** DR. McGREW HAS WORKED OUT THE INFRARED ABSORPTION STRENGTHS OF WATER VAPOR AND CARBON DIOXIDE WHICH ARE SHOWN HERE. THIS FIGURE SHOWS THAT AT 800 PPM IN THE ATMOSPHERE, 70% OF THE EARTH’S EMITTED INFRARED IS ABSORBED BY WATER VAPOR WHILE ONLY 2% IS ABSORBED BY CO<sub>2</sub>. A SMALL MASS OF H<sub>2</sub>O IS VERY EFFECTIVE IN ABSORBING THERMAL RADIATION.

THESE DATA ARE TAKEN FROM EXPERIMENTS BY H. C. HOTTEL AT MIT, AND INDEPENDENTLY CONFIRMED BY ELSASSER AND CULBERTSON. THEY

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SHOW THAT THE ABSORBTIVITY-EMISSIVITY INCREASES LOGARITHMICALLY TO THE CONCENTRATION. THE ABSORBTIVITY-EMISSIVITY OF WATER VAPOR, ICE AND LIQUID ALL HAVE THIS SAME CURVE AND REACH 96% AT 10,000 PPM. THE ATMOSPHERE HOLDS ON AVERAGE 20,000 PPM OF WATER.

**SLIDE 41.** THIS IS A BLOW UP OF THE LAST SLIDE, AND SHOWS WHAT HAPPENS IF CO<sub>2</sub> IS DOUBLED FROM 380 PPM (CURRENT LEVEL) TO 800 PPM. IT HAS ALREADY ABSORBED AT 150 PPM, AND CERTAINLY AT 380 PPM ESSENTIALLY ALL THE EARTH'S EMITTED THERMAL ENERGY IT CAN ABSORB. EVEN IF THERE WERE NO WATER VAPOR FROM 400 PPM TO 800 PPM THE EFFECT OF CO<sub>2</sub> WOULD NOT BE GREAT. SINCE 80% OF THE EARTH'S SURFACE IS COVERED BY WATER AND ICE THE TRUE CURVE MUST BE CLOSE TO THE LOWER CURVE.

**SLIDE 42.** THIS SLIDE SHOWS THAT 57% OF THE THERMAL RADIATION IS EMITTED FROM THE TROPICS WHERE WATER VAPOR IS ESPECIALLY PREVALENT AT THE 30,000 TO 40,000 PPM LEVEL. THUS WHERE RADIATION IS GREATEST IS WHERE WATER IS MOST PREVALENT.

**SLIDE 43.** THIS SLIDE BY LINDZEN SHOWS A SIMILAR LOGARITHMIC PROJECTION FOR CO<sub>2</sub> WITH TOTALLY CLEAR SKIES. THE CURVE IS BASED ON A

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MODEL BASED ON SEVERAL ASSUMPTIONS. LINDZEN IS THE SLOAN PROFESSOR OF METEOROLOGY AT MIT AND A PAST PRESIDENT OF THE NATIONAL ACADEMY OF SCIENCE. HE INCREASED CO<sub>2</sub> FROM 300 TO 600 PPM WITH CLEAR SKIES AND CALCULATED A TEMPERATURE INCREASE OF 0.64°C. HOWEVER, WITH LESS THAN AVERAGE CLOUDINESS (40%) HE GOT ONLY A 0.22°C INCREASE. CLOUD COVER AVERAGES 62%. HE DOES NOT BELIEVE CO<sub>2</sub> IS SIGNIFICANT IN GLOBAL WARMING.

WHAT HAVE WE SAID: THE THERMODYNAMIC EVIDENCE SUGGESTS THAT CO<sub>2</sub> CANNOT BE A MAJOR CONTRIBUTOR TO GLOBAL WARMING.

**SLIDE 44.** WELL, LET'S DISCUSS MODELS. ACCORDING TO ERIC BARRON AT THE UNIVERSITY OF TEXAS THERE ARE APPROXIMATELY 30 CURRENTLY RECOGNIZED MODELS, TWELVE OF WHICH HAVE COME CLOSE TO SIMULATING THE LAST CENTURY. ALL TWELVE GIVE DIFFERENT RESULTS FOR THE NEXT HUNDRED YEARS. THE BEST MODELS IN THE U.S. ARE NASA, NOAA AND NCAR.

**SLIDE 45.** THIS SLIDE SHOWS A FLOW DIAGRAM FOR CLIMATE MODELING. THIS DOESN'T BEGIN TO INCLUDE EVERYTHING AND OF COURSE, THE MODELS ARE ONLY AS GOOD AS THE QUALITY OF THE INDIVIDUAL AREAS THAT THEY COMPOSITE. TO MAKE IT MANAGEABLE THE AREAS USED IN MODELS ARE LARGE AND THEY CAN CONTAIN UP TO THREE OR FOUR DIFFERENT WEATHERS

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AT ANY ONE TIME. THIS IS A MASSIVELY COMPLICATED PHYSICAL SET OF PROCESSES WITH MULTIPLE NON-LINEAR FEEDBACK LOOPS. ROBOCK AND MANY OTHERS, INCLUDING LINDZEN, BELIEVE IT IS IMPOSSIBLE.

**SLIDE 46.** SHOWN HERE IS AN ILLUSTRATION TAKEN FROM THE LATEST IPCC REPORT WHICH JUST CAME OUT. SIX DIFFERENT MODEL PROJECTIONS FOR TEMPERATURE SHOW A RISE OVER THE NEXT ONE HUNDRED YEARS RANGING FROM 1.1°C TO 6.4°C.

**SLIDE 47.** THE INPUT TO THE MODELS VARIES RATHER DRAMATICALLY. THE REPORT COMPARES ESTIMATES FOR AEROSOL DIRECT RADIATION FORCING FOR EIGHT OF THE MODELS PUBLISHED SINCE THE LAST 2001 REPORT. THERE IS A COMPARATIVE DIFFERENCE RANGE OF FROM 1 TO 64.

**SLIDE 48.** THIS SLIDE SHOWS THE CLOUD ALBEDO EFFECT OF SOME TWENTY (20) MODELS AND THE RELATIVE RANGE IS 1 TO 5.

**SLIDE 49.** TO BE EFFECTIVE COMPUTER MODELS MUST BE ABLE TO BACK MODEL RECORDED CLIMATE HISTORY AND NONE OF THEM THUS FAR HAVE BEEN ABLE TO REPLICATE THE MEDIEVAL CLIMATE OPTIMUM OR THE ROMAN WARM EVENTS.

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WHAT HAVE WE SAID: THE GLOBAL CLIMATE IS INFINITELY COMPLEX AND WE STILL HAVE A VERY POOR UNDERSTANDING OF THE VARIOUS ELEMENTS OF THIS COMPLEX SYSTEM. I DO NOT THINK WE SHOULD BASE ANY IMPORTANT SOCIAL OR ECONOMIC DECISIONS ON MODELS.

**SLIDE 50.** WELL, WHAT DO WE KNOW ABOUT SUN SPOTS – THAT THEY CAN BE 700 TIMES LARGER THAN THE SURFACE OF THE EARTH –  $E + MC^2$  IS DRIVING IT – THE SUN IS REALLY HOT – THE INTENSITY OF SUN SPOTS SEEMS TO CORRELATE WITH TEMPERATURE. DURING THE LITTLE ICE AGE IN THE MIDDLE TO LATE 1600s THERE WERE ALMOST NO SUN SPOTS.

**SLIDE 51.** THIS SLIDE SHOWS THE CONVEYOR BELT ON THE SUN BETWEEN THE CORE AND THE EXTREMITY – A MASSIVE CIRCULATING CURRENT OF HOT PLASMA. THE CONVEYOR BELT TAKES APPROXIMATELY 40 YEARS TO COMPLETE A CIRCUIT AND IT MOVED AT ABOUT 1 METER PER SECOND FOR MUCH OF THE 20<sup>TH</sup> CENTURY. HOWEVER, IT HAS BEEN SLOWING IN RECENT YEARS (0.75 TO 0.35 M/S). THE SLOWER BELT FORETELLS LOWER SOLAR ACTIVITY.

**SLIDE 52.** THIS SLIDE SHOWS THE SOLAR CYCLE INTENSITY AND A PREDICTION BASED ON THE DRIFT WE JUST DISCUSSED. DAVID HATHAWAY AT

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NASA HAS PREDICTED THAT CYCLES 24 AND 25 WILL LOOK AS SHOWN. THEY PREDICT CYCLE 25 IS GOING TO BE CONSIDERABLY LOWER, AND THE PROJECTED TREND SINCE 1990 IS DOWNWARD.

**SLIDE 53.** THIS SLIDE BY HOYT AND SCHATTEN SHOWS A RATHER GOOD CORRELATION BETWEEN SOLAR CYCLE LENGTH AND TEMPERATURE – HOWEVER, CORRELATION DOES NOT NECESSARILY PROVE CAUSATION, AND IN THE LAST 10 YEARS, NOT SHOWN HERE, THE GLOBAL TEMPERATURE (NOT THE U.S. TEMPERATURE) HAS GONE UP, WHILE SOLAR INDICATORS HAVE LEVELED OFF OR STARTED DOWN.

**SLIDE 54.** IN THIS SLIDE BERNER HAS SHOWN THAT TEMPERATURE FROM A GREENLAND ICE CORE AND SUNSPOT ACTIVITY PROJECTED BACK TO 900 A.D., USING  $C_{14}$  AS A PROXY, HAVE A FAIRLY GOOD CORRELATION. AGAIN NOTE THIS DOES NOT SHOW THE LAST 10 YEARS.

**SLIDE 55.** MARSH AND SVENSMARK HAVE STUDIED COSMIC RAY INTENSITY AND CLOUD COVER. THEY FIND THAT FOR ALL CLOUDS FROM 1985 TO 1995 (A VERY SHORT TIME) THERE IS A STRONG CORRELATION BETWEEN COSMIC RAYS AND CLOUD COVER. FOR THE LAST 10 YEARS THE LOWER CLOUDS CONTINUE TO CORRELATE BUT UPPER CLOUDS DO NOT. DURING INCREASED SUN ACTIVITY, SOLAR MAGNETIC FIELDS (THE SOLAR WINDS) DRIVE PART OF THE

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COSMIC RADIATION AWAY FROM THE EARTH – FEWER CLOUDS ARE FORMED IN THE TROPOSPHERE AND THE EARTH BECOMES WARMER BECAUSE OF DECREASED ALBEDO.

**SLIDE 56.** SO SOLAR ACTIVITY, INCLUDING THE SUN SPOTS AND SOLAR ERUPTIONS CAUSE ENHANCED THERMAL ENERGY FLUX AND MORE INTENSE SOLAR WIND. SOLAR WIND ATTENUATES THE COSMIC RAY FLUX – THIS IS A CONSTANT BOMBARDMENT OF OUR PLANET BY COSMIC RAYS. THE COSMIC RAY FLUX CORRELATES CONVINCINGLY WITH LOW ALTITUDE CLOUD COVER BUT, BY THE WAY, IN THE LAST 10 YEARS NOT VERY CONVINCINGLY AT ALL WITH MEDIUM AND HIGH CLOUDS.

SO WHAT MAY BE POSSIBLE IS THAT A (1) BRIGHTER SUN, (2) WITH ENHANCED THERMAL FLUX PLUS SOLAR WIND (3) GIVES A MUTED COSMIC RAY FLUX, (4) LESS LOWER LEVEL CLOUDS, (5) LESS ALBEDO AND A WARMER CLIMATE. THUS GREATER SOLAR IRRADIANCE IS RELATED TO LESS LOW CLOUD COVER AND LESS ALBEDO AND THEREFORE WARMER CLIMATE. THIS COMBINED EFFECT MAY BE VERY IMPORTANT.

**SLIDE 57.** WITH THESE NEXT MISCELLANEOUS SLIDES I WANT TO DISPEL SOME MISCONCEPTIONS. THE FAMOUS HOCKEY STICK SHOWN HERE FEATURED IN THE IPCC 2001 REPORT WAS BY MANN, ET AL. BRISTLECONE PINE DATA WAS

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NOT RECOMMENDED BEFOREHAND BUT WAS GIVEN 390 TIMES THE WEIGHTING OF ANY OTHER PARAMETERS BY MANN, ET AL. THEY LEFT OUT A SET OF DATA AND THEY ELIMINATED THE MEDIEVAL OPTIMUM AND THE LITTLE ICE AGE.

**SLIDE 58.** McINTYRE AND McKITRICK WERE ABLE TO USE RANDOM NOISE AND MANN'S ALGORITHM TO GET THE SAME CURVE. WHEN THEY WERE ABLE TO GET THE DATA, WHICH MANN, ET AL. WITHHELD FOR A LONG TIME, THE CORRECTED VERSION DID RECREATE THE MEDIEVAL WARM EVENT AND THE LITTLE ICE AGE.

**SLIDE 59.** THE NATIONAL ACADEMY OF SCIENCE QUOTE "MANN'S PRINCIPLE COMPONENTS WERE BIASED TOWARD PRODUCING A HOCKEY STOCK-SHAPED SERIES." THEY ALSO CRITICIZED MANN, ET AL. FOR (1) USING BRISTLECONE PINE TREE RINGS, (2) THEIR RECONSTRUCTION FAILING IMPORTANT VERIFICATION TESTS, AND (3) STATED THAT HIS DATA DID NOT SUPPORT THE IDEA THAT THE 1990S WERE THE WARMEST DECADE IN THE LAST MILLENNIUM.

**SLIDE 60.** THIS IS A LOOK AT ALL THE HURRICANES AND THE MAJOR HURRICANES FROM 1945 – 2006. THERE IS NO DIFFERENCE.

**SLIDE 61.** OF REAL CONCERN FOR USING DATA FROM BUBBLES IN ICE CORES FROM ANTARCTICA IS THE FACT THAT THE SURFACE TEMPERATURE AT THE

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SOUTH POLE HAS NOT GONE UP WITH EITHER CO<sub>2</sub> OR TEMPERATURE RISES AS RECORDED GLOBALLY.

**SLIDE 62.** THE POLAR BEARS' WORLD POPULATION IS 22,000. REGIONS WITH THE GREATEST TEMPERATURE INCREASE HAVING RISING BEAR POPULATIONS, AND THE OTHER AREAS ARE RELATIVELY STABLE. POLAR BEARS SURVIVED THE ROMAN MAXIMUM WHICH WAS MUCH HOTTER THAN THE PRESENT.

**SLIDE 63.** CONCLUSIONS

- CLIMATE IS CONSTANTLY CHANGING. IT HAS BEEN WARMING FOR THE LAST 300 YEARS AND CERTAINLY THE LAST 25 YEARS.
- GEOLOGIC HISTORICAL CHANGES HAVE BEEN DOMINATED BY NATURAL PROCESSES.
- OCEAN CURRENTS DICTATED BY PLATE MOVEMENTS HAVE BEEN VERY IMPORTANT.
- CO<sub>2</sub> IS A SECOND ORDER GREENHOUSE GAS AFTER WATER VAPOR.
- MAN HAS INTRODUCED A LOT OF CO<sub>2</sub> INTO THE ATMOSPHERE.

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- UP TO A CONCENTRATION OF ABOUT 150 PPM CO<sub>2</sub> CAN PLAY A VERY IMPORTANT ROLE IN GLOBAL WARMING. BEYOND 150 PPM ITS ROLE DIMINISHES.
- THE HISTORY OF CO<sub>2</sub> MAY BE MUCH MORE COMPLICATED THAN PREVIOUSLY THOUGHT.
- ICE CORE DATA FROM THE PLEISTOCENE AND MORE RECENT DATA INDICATE TEMPERATURE DRIVES CO<sub>2</sub>.

### **SLIDE 64.** CONCLUSIONS.

- THE EARTH'S CLIMATE IS A DYNAMIC, NONLINEAR INTER-DEPENDENT COMPLEX SYSTEM AND MAY BE IMPOSSIBLE TO MODEL EFFECTIVELY.
- VARYING DEGREES OF SOLAR ACTIVITY SEEM TO CORRELATE WELL WITH TEMPERATURE; HOWEVER, THERE IS A DIVERGENCE IN THE DATA FOR THE LAST 10 YEARS.
- COSMIC RAYS MAY PLAY A SIGNIFICANT ROLE IN TEMPERATURE PATTERNS.

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- AT THIS TIME THERE IS NO ROCK HARD EVIDENCE THAT THE SUN OR THAT CO<sub>2</sub> ARE NECESSARILY CONTROLLING CURRENT TEMPERATURES.
- CLOUDS – THEIR INCREASES AND DECREASES ARE CRITICAL TO TEMPERATURE CHANGES AND ARE VERY POORLY UNDERSTOOD AND MAY BE THE MISSING LINK IN THE EQUATION.
- MORE RESEARCH NEEDS TO BE FOCUSED ON THE CAUSES (SUCH AS CLOUDS) RATHER THAN THE EFFECTS OF CLIMATE CHANGE.