

Planet Earth

Climate Puzzle

- 1 03:01:44:07 AT ANY MOMENT, LIGHTNING STRIKES THE EARTH 1000 TIMES A SECOND.
- 2 03:01:50:07 COUNTLESS STORMS TEAR THROUGH THE ATMOSPHERE.
- 3 03:01:53:07 THESE PHENOMENA ARE FLEETING GLIMPSES OF A FAR MORE POWERFUL FORCE.
- 4 03:01:59:05 A GLOBAL SEARCH IS UNDERWAY TO UNRAVEL THE MYSTERIES OF EARTH'S CLIMATE, WHICH CHANGES, OVER TIME, AS DRAMATICALLY AS THE SEASONS.
- 5 03:02:08:24 ONLY NOW ARE SCIENTISTS BEGINNING TO FIND OUT HOW AND WHY.
- 6 03:02:14:10 THEIR SEARCH BEGINS WITH THE FRAGMENTS OF A GIANT PUZZLE COLLECTED FROM AROUND THE WORLD.
- 7 03:02:21:09 AN INCREDIBLE SAGA IS UNFOLDING OF DROUGHTS AND SEARING COLD, OF WARM SPELLS AND EONS OF ICE.
- 8 03:02:31:25 THE PIECES ARE EVERYWHERE -- IN THE CORALS OF A CARRIBEAN PARADISE AND BENEATH THE SANDS OF INDIA, IN THE POLLEN OF SIMPLE PLANTS.
- 9 03:02:43:22 THEY CAN BE FOUND IN A LIMESTONE CAVE IN NEW ZEALAND AND IN THE HIGH REACHES OF THE SWISS ALPS.
- 10 03:02:53:12 THERE ARE PIECES OF THE PUZZLE IN ANTARCTIC DESERT STONES AND IN SHELLS OF MICROSCOPIC CREATURES FOUND AT THE BOTTOM OF THE SEA.
- 11 03:03:04:13 IN THESE CLAY SKYSCRAPERS ON AFRICA'S PLAINS, TINY CREATURES THAT FAR OUTNUMBER HUMANKIND ARE HELPING TO CHANGE THE AIR WE BREATHE.
- 12 03:03:15:24 IN A CITADEL OF CLIMATE RESEARCH IN COLORADO, SCIENTISTS HAVE CREATED AN ELECTRONIC

CRYSTAL BALL.

- 13 03:03:23:07 WITH IT, THEY PLOT EARTH'S ANCIENT CLIMATE AND PEER INTO THE FUTURE BEYOND OUR LIFETIME.
- 14 03:03:30:12 THE PICTURE NOW EMERGING SHOWS DRAMATIC CLIMATE CHANGES AFFECTING THE ENTIRE PLANET.
- 15 03:03:36:08 JOIN US ON AN INTRIGUING JOURNEY ACROSS TIME AND CONTINENTS AS SCIENTISTS PIECE TOGETHER THE PUZZLE OF EARTH'S CHANGING CLIMATE.
- 16 03:03:52:07 CAPTIONING IS MADE POSSIBLE BY THE ANNENBERG/CPB PROJECT
- 17 03:04:23:03 cgqs
- 18 03:04:23:03 Annenberg Media
- 19 03:04:26:17 §
- 20 03:04:33:11 s IBM IS PROUD TO SUPPORT THE SPIRIT OF SCIENTIFIC INQUIRY THAT MADE THIS SERIES POSSIBLE.
- 21 03:04:40:22 AMID A LAND OF GREAT ICE LIES THE STRANGEST DESERT IN THE WORLD.
- 22 03:04:47:12 200-MILE-AN-HOUR WINDS AND TEMPERATURES 100 DEGREES BELOW ZERO MAKE ANTARCTICA'S DRY VALLEYS ONE OF EARTH'S MOST INHOSPITABLE PLACES.
- 23 03:04:57:01 HERE, AN UNUSUAL TALE OF CLIMATE AND LIFE IS UNFOLDING.
- 24 03:05:01:09 NOT EVEN THE SOPHISTICATED DEVICES EXPLORING OTHER PLANETS COULD HAVE FOUND WHAT SCIENTISTS FOUND HERE.
- 25 03:05:08:25 EACH ANTARCTIC SUMMER SINCE 1976, RESEARCHERS HAVE COME TO STUDY A PRIMITIVE FORM OF LIFE FOUND NOWHERE ELSE.
- 26 03:05:17:23 ANTARCTICA'S CLIMATE IS SO HOSTILE, IT HAS DRIVEN LIFE TO TAKE REFUGE INSIDE AMONG THE PORES OF ANCIENT ROCK.

- 27 03:05:26:28 I'LL CHOP OFF A PIECE OF ROCK.
- 28 03:05:30:09 FOR FIVE DAYS EACH YEAR, THE SUN WARMS THE ROCK ENOUGH FOR TINY ORGANISMS TO BREAK SLUMBER.
- 29 03:05:38:06 FROM THE ROCK, THEY TAKE NOURISHMENT, AND FROM THE AIR, SCARCE MOISTURE.
- 30 03:05:44:08 QUICKLY THEY REPRODUCE, THEN BECOME DORMANT UNTIL NEXT YEAR'S SUMMER SUN WAKES THEM AGAIN.
- 31 03:05:51:09 1/10 OF AN INCH BELOW THE SURFACE, THE MICROBES ARE SAFE FROM THE VICIOUS CLIMATE.
- 32 03:05:58:22 EACH DARK BAND IS A MINIATURE ECOSYSTEM.
- 33 03:06:02:10 LONG STRANDS OF FUNGI AND CLUSTERS OF ALGAE JOIN TO FORM LICHEN GROWING AMONG THE ROCK CRYSTALS.
- 34 03:06:10:13 THE MICROBES ACTUALLY CHANGE SHAPE TO FIT THIS UNUSUAL HABITAT.
- 35 03:06:15:12 TO LEARN HOW LIFE CAN EXIST HERE, THE SCIENTISTS PROVIDE NUTRIENTS TO THE ORGANISMS.
- 36 03:06:22:07 THE ORGANISMS MAY GROW SO SLOWLY BECAUSE THEY ARE DEFICIENT IN SOME ESSENTIAL NUTRIENTS.
- 37 03:06:28:28 OVER YEARS, WE MAY SEE A STIMULATION IN GROWTH.
- 38 03:06:33:09 IN ANOTHER EXPERIMENT, SCIENTISTS CREATE ARTIFICIAL GREENHOUSES TO LENGTHEN THE MICROBES' GROWING SEASON TO DISCOVER HOW LIFE CHANGES AS CLIMATE CHANGES.
- 39 03:06:45:06 IF WE LEAVE THESE GUYS OUT FOR THREE OR FOUR YEARS, THE HEAT CREATED BY THE GREENHOUSE EFFECT SHOULD WARM UP THE ROCK SO THAT THE ORGANISMS WILL HAVE A BETTER CHANCE OF GROWING.
- 40 03:07:05:24 HERE IN THE MOST BARREN ENVIRONMENT ON

- EARTH, LIFE FITS INSIDE NEARLY EVERY LOOSE ROCK.
- 41 03:07:13:09 IT NOW SEEMS CLEAR THAT LIFE ON EARTH IS DRAMATICALLY SHAPED BY EARTH'S CLIMATE.
- 42 03:07:25:19 THROUGH EONS OF EVOLUTION, LIFE ON EARTH HAS DEVELOPED STRATEGIES TO COPE WITH THE CHANGING CLIMATE.
- 43 03:07:34:07 DRIVEN BY SOME MYSTERIOUS INTERNAL TIME CLOCK, SOME BIRDS TRAVEL THOUSANDS OF MILES EACH YEAR TO ESCAPE THE ONSET OF WINTER.
- 44 03:07:47:12 ANIMALS THAT CANNOT FLEE MEET THE CHALLENGE OF A CLIMATE TURNED EXTREME IN NUMEROUS AND INGENIOUS WAYS.
- 45 03:07:56:00 THEY ADAPT BY FORAGING OR HIBERNATION.
- 46 03:08:11:09 THE GREAT CHAIN OF LIFE REFLECTS THE CONTINUING DRAMA OF EARTH'S CHANGING CLIMATE.
- 47 03:08:24:02 THE FATE OF HUMAN ENDEAVOR MAY ALSO BE LINKED TO OUR INCONSTANT EARTH.
- 48 03:08:30:09 AN UNUSUALLY BENIGN CLIMATE COINCIDED WITH THE RISE OF CIVILIZATION -- - PERHAPS EVEN FOSTERED ITS DEVELOPMENT.
- 49 03:08:37:21 CIVILIZATIONS FIRST FLOURISHED IN REGIONS THAT ARE TRULY HARSH TODAY -- IN SEARING SANDS OF THE ANCIENT MIDDLE EAST.
- 50 03:08:48:29 THE INESCAPABLE EFFECTS OF CLIMATE CHANGE ALSO MAY HAVE BEEN A FACTOR IN HUMAN UPHEAVALS THROUGHOUT HISTORY.
- 51 03:08:56:23 SOUTH OF THE HIMALAYAS, WHERE INDIA MEETS PAKISTAN, LIES THE GREAT RAJASTHAN DESERT, THE MOST POPULATED ARID REGION ON EARTH.
- 52 03:09:10:18 FOR THOUSANDS OF YEARS, PEOPLE HAVE SCRATCHED LIVINGS FROM HERE.
- 53 03:09:15:19 ON SPARSE DESERT GRASSES, THEY RAISE DOMESTICATED ANIMALS AND CAREFULLY GUARD WHAT LITTLE WATER CAN BE FOUND.

- 54 03:09:24:08 HERE, WATER IS MORE PRECIOUS THAN GOLD, COMING BUT ONCE A YEAR.
- 55 03:09:34:02 FOR WEEKS AT A TIME, THE MONSOON LASHES INDIA WITH STEADY SHEETS OF RAIN.
- 56 03:09:40:25 USUALLY, SUMMERS ARE WET, AND WINTERS ARE DRY, BUT THE MONSOON REVERSES THE PATTERN.
- 57 03:09:57:03 THE MONSOON HAS FUELED THE INDIAN BREADBASKET FOR MILLENIA.
- 58 03:10:06:28 IN THE RAJASTHAN DESERT, THESE TEMPLES AT OSIAN BEAR MUTE TESTIMONY TO THE SPIRITUAL VALUES OF AN ANCIENT, PROSPEROUS CIVILIZATION.
- 59 03:10:16:22 THEY'RE SYMBOLS OF MANY CULTURES THAT HAVE DISAPPEARED -- CAUGHT IN THE VAGARIES OF TIME AND CLIMATE.
- 60 03:10:25:22 AS ARCHAEOLOGISTS RECOVER THE RUINS FROM THE SANDS, SCIENTISTS HAVE DISCOVERED AN ARCHAEOLOGY OF CLIMATE.
- 61 03:10:33:19 THE ANCIENT CITY OF LOTHAL, THE HARAPPAN CULTURE'S SEAPORT, NOW LANDLOCKED BY THE DESERT SANDS.
- 62 03:10:41:06 FOR A THOUSAND YEARS, THE HARAPPANS PROSPERED HERE AS FARMERS AND DISTRIBUTORS OF GRAIN.
- 63 03:10:47:15 THEN, MYSTERIOUSLY, THEY DISAPPEARED.
- 64 03:10:49:19 CLIMATE HISTORIAN REID BRYSON OF THE UNIVERSITY OF WISCONSIN IS AN EXPERT ON THE MONSOONS.
- 65 03:10:57:05 HIS ADVICE IS CRITICAL TO THE REGION'S FARMERS.
- 66 03:11:01:07 WE'LL HAVE ABOVE NORMAL PRECIPITATION.
- 67 03:11:04:07 BRYSON ALSO WONDERS ABOUT THE HARAPPANS' DISAPPEARANCE.
- 68 03:11:07:21 MANY ARCHAEOLOGISTS BELIEVED THEY WERE WEAKENED BY A SUCCESSION OF INVASIONS.

- 69 03:11:13:07 BRYSON WENT TO SAMBHAR SALT LAKE, WHERE HE FOUND ANOTHER ANSWER.
- 70 03:11:19:07 STRATIFIED LAKE SEDIMENTS ARE LIKE A BOOK IN WHICH THIS REGION'S CLIMATE HISTORY IS WRITTEN.
- 71 03:11:26:21 IN THOSE LAYERS, EACH YEAR IN ITS HISTORY OVER THE LAST 10,000 YEARS, PLANT POLLEN, SAND, VARIOUS THINGS HAVE BLOWN IN AND ACCUMULATED.
- 72 03:11:40:07 WE KNOW HOW TO LOOK AT THAT ASSEMBLAGE OF VARIOUS KINDS OF PLANT POLLEN AND CHARCOAL AND SAND, AND INTERPRET IT TO READ THE WRITING OF HISTORY IN THIS LAKE SEDIMENT.
- 73 03:11:57:26 THE POLLEN LAYERS REVEALED A PROLONGED DROUGHT, A TIME WHEN THE MONSOONS FAILED AND THE HARAPPAN CULTURE COLLAPSED.
- 74 03:12:06:09 A QUARTER MILLION PEOPLE MAY HAVE PERISHED IN THE D@SERT.
- 75 03:12:13:24 TODAY, HUNDREDS OF MILLIONS DEPEND ON THE RETURN OF THE MONSOONS.
- 76 03:12:19:15 THE STUDY OF ANCIENT CIVILIZATIONS REVEALS THAT THE PAST CAN LEAVE LONG SHADOWS AFFECTING THE PRESENT AND FUTURE.
- 77 03:12:31:23 THE RECORDS LEFT IN THE RAJASTHAN COVER AN INSTANT IN THE HISTORY OF EARTH'S CLIMATE.
- 78 03:12:39:08 IN A LIMESTONE CAVE IN NORTHERN NEW ZEALAND, THE SLOW DRIP OF WATER HAS CREATED A LONGER RECORD.
- 79 03:12:47:22 HERE, SCIENTISTS HAVE BECOME EXPLORERS.
- 80 03:12:50:06 WITH HEADLAMPS AND PROTECTIVE GEAR, THEY SEEK TO PUSH THE CLIMATE RECORD BACK FURTHER IN GEOLOGIC TIME.
- 81 03:12:58:22 GEOCHEMISTS CHRIS AND VIVIAN HENDY.
- 82 03:13:01:09 THIS IS THE SPOT.
- 83 03:13:03:09 THIS IS WHERE WE SET UP PLASTIC TUBING TO

COLLECT WATER FOR RADIOCARBON DATING.

- 84 03:13:10:01 THE NEXT PROBLEM WAS FINDING A STALAGMITE OR STALACTITE WHICH WOULD GIVE US A SUITABLY LONG TIME RECORD FOR OXYGEN ISOTOPE ANALYSIS.
- 85 03:13:21:09 THESE STRAWS GROW A FEW METERS, THEN DROP OFF.
- 86 03:13:25:21 IT'S BETTER IF WE GOT STALAGMITES.
- 87 03:13:29:17 AS WATER AND MINERALS SEEP THROUGH THE GROUND ABOVE, THEY CREATE THE DELICATE ARCHITECTURE OF THE CAVE.
- 88 03:13:37:06 SOME MINERALS, DEPOSITED WHEN THE CLIMATE WAS COLD, DIFFER FROM THOSE DEPOSITED WHEN IT WAS WARM.
- 89 03:13:45:08 THE MINERALS CREATE A CHEMISTRY EXTRACTABLE AS AN HISTORICAL RECORD OF THE WORLD'S CLIMATE.
- 90 03:13:52:06 DRIP BY DRIP, THE CAVE FORMS BEFORE OUR EYES.
- 91 03:13:55:07 FORMATIONS LIKE THESE HAVE BEEN CREATED OVER TENS OF THOUSANDS OF YEARS, AND WITH THEM, A PERFECT RECORD IN CHANGE OF TEMPERATURE AND MOISTURE.
- 92 03:14:09:26 CONCERNED ABOUT PRESERVING THE CAVE'S FRAGILE BEAUTY, HENDY AND HIS PARTY HAVE HIKE A MILE THROUGH ANKLE-DEEP WATER TO LOOK FOR A REMOVABLE SPECIMEN.
- 93 03:14:22:09 THERE'S THE ONE WE FINALLY TOOK.
- 94 03:14:25:09 IT WAS A STALACTITE THAT WAS ALREADY BROKEN, PROBABLY PART OF A COLUMN THAT WAS JOINED TO THE FLOOR, BUT THE FLOOR DROPPED AWAY.
- 95 03:14:37:20 WE HAD A FULL 100,000-YEARS' RECORD FROM ITS WIDTH.
- 96 03:14:46:07 HENDY COLLECTS WATER FROM THESE ANCIENT STALACTITES.

- 97 03:14:49:22 THE MINERAL CONTENT HELPS DETERMINE THE AGE OF THE FORMATIONS.
- 98 03:14:58:15 AT WAIKATO UNIVERSITY, HENDY DATES AND ANALYZES THE LIMESTONE LAYER BY LAYER.
- 99 03:15:08:10 HIS RESEARCH CONFIRMED A HISTORY CHRONICLED BY THE ARTISTS OF ANOTHER TIME AND PLACE.
- 100 03:15:15:24 AS DUTCH ARTISTS CREATED THEIR FAMOUS LANDSCAPES, THEY DOCUMENTED A DRAMATIC SHIFT IN EARTH'S CLIMATE.
- 101 03:15:23:20 TODAY, THE DUTCH CANALS RARELY FREEZE, BUT IN THE 17th CENTURY, MORE THAN THREE CENTURIES OF UNUSUALLY SEVERE WINTERS PLUNGED EUROPE INTO WHAT SCIENTISTS CALL THE LITTLE ICE AGE.
- 102 03:15:37:14 A HUNDRED YEARS AGO, THE IDEA OF AN ICE AGE WAS INCONCEIVABLE.
- 103 03:15:43:07 A FEW INTREPID SCIENTISTS HAD SUGGESTED THE POSSIBILTY, BUT THEY WERE IGNORED.
- 104 03:15:49:07 IN THE MID-19th CENTURY, A PICTURE BEGAN EMERGING OF A TIME WHEN EARTH'S CLIMATE WAS DRAMATICALLY DIFFERENT -- WHEN ICE RULED THE WORLD.
- 105 03:16:00:11 FOR HUNDREDS OF YEARS, THESE TOWERING WALLS AND PRECARIOUSLY PERCHED BOULDERS MYSTIFIED ALL WHO SAW THEM.
- 106 03:16:11:24 MOST THOUGHT THEY WERE SWEEPED HERE BY THE GREAT FLOOD DESCRIBED IN THE BIBLE.
- 107 03:16:18:25 BUT IN 1837, ANOTHER PERSISTENT OBSERVER HAD A DIFFERENT IDEA.
- 108 03:16:25:26 HERE IN THE SWISS RESORT TOWN OF NEUCHATEL, A YOUNG SCIENTIST'S IDEAS IGNITED A VIOLENT SCIENTIFIC DISPUTE.
- 109 03:16:35:00 SWISS NATURALIST LOUIS AGASSIZ SHOCKED THE SCIENTIFIC ESTABLISHMENT BY DECLARING THAT THE WORLD AROUND THEM WAS ONCE COVERED BY ICE MORE THAN A MILE THICK.

- 110 03:16:47:16 TO SUPPORT HIS THEORY, AGASSIZ POINTED TO THE STRANGE BOULDERS.
- 111 03:16:53:09 HE MATCHED THEIR GEOLOGY TO MOUNTAINS HUNDREDS OF MILES AWAY.
- 112 03:16:58:22 THE ROCKS WERE TOO LARGE TO HAVE BEEN MOVED BY FLOOD WATER.
- 113 03:17:04:23 NEARBY, IN HUGE SHEETS OF ROCK, HE FOUND GROOVES AND CHANNELS.
- 114 03:17:13:24 ELSEWHERE, HE OBSERVED BEDROCK THAT WAS AMAZINGLY FLAT, AS IF SHEARED BY A GIANT KNIFE.
- 115 03:17:25:05 IN HIS NOTEBOOKS, AGASSIZ VIVIDLY ILLUSTRATED A DISTANT EPOCH OF EXTREME COLD WHEN ICE COVERED MUCH OF THE EARTH.
- 116 03:17:34:04 HE CALLED IT AN *EISZEIT*, OR ICE AGE.
- 117 03:17:37:05 WHAT WAS A RADICAL IDEA FOR SCIENCE WAS OBVIOUS TO THOSE WHO LIVED HERE.
- 118 03:17:44:07 THE CHAMOIS HUNTERS OF THE HIGH ALPS HAD IDENTIFIED THE ROCKS AS BROKEN PIECES OF DISTANT MOUNTAINS MOVED ACROSS THE LAND BY GLACIERS.
- 119 03:17:55:22 THE LOST ROCKS, LIKE LOST SHEEP, WERE CALLED FOUNDLINGS.
- 120 03:18:00:13 AGASSIZ HAD HEARD THESE TALES.
- 121 03:18:02:25 FROM THESE SIMPLE, ELEGANT INTUITIONS, HE DEFINED HIS SCIENTIFIC THEORIES.
- 122 03:18:07:25 TO CONVINC OTHERS, AGASSIZ ORGANIZED FIELD TRIPS TO THE GLACIERS, A TRADITION STILL OBSERVED BY SCIENTISTS.
- 123 03:18:16:09 THESE GLACIER WALLS ARE JUST AS DRAMATIC TODAY.
- 124 03:18:20:10 TO AGASSIZ, THEY WERE GOD'S GREAT PLOW THAT SLOWLY BUT STEADILY CARVED AND SHAPED THE VALLEYS BELOW.

- 125 03:18:30:24 AGASSIZ ARGUED THAT GLACIERS WERE THE REMNANTS OF A TIME WHEN ICE NOT ONLY COVERED SWITZERLAND, BUT STRETCHED FROM THE NORTH POLE TO THE MEDITERRANEAN SEA.
- 126 03:18:48:03 EACH SUMMER, SCIENTISTS RETURN TO EXPLORE THE GLACIERS OF THE HIGH ALPS.
- 127 03:18:54:06 THEY HIKE AMONG THE ROCK AND ALONG RIDGES THAT SO INTRIGUED LOUIS AGASSIZ.
- 128 03:19:10:27 A GLACIER IS VIRTUALLY A RIVER OF ICE.
- 129 03:19:14:29 IT SCOURS EVERYTHING IN ITS PATH.
- 130 03:19:18:00 LIKE A RIVER, IT FLOWS AT VARYING SPEEDS TO CREATE TREACHEROUS CURRENTS CALLED CREVASSES.
- 131 03:19:24:23 HUNDREDS OF FEET DEEP, THEY CAN DISAPPEAR ALMOST OVERNIGHT -- COLLAPSED BY THE CONTINUOUS ONSLAUGHT OF THE ICE.
- 132 03:19:33:15 NEARLY ONE HALF OF THE EARTH'S LANDSCAPE HAS BEEN CARVED BY SUCH UNCEASING FORCE.
- 133 03:19:40:07 EVENTUALLY, WE FOUND THAT NUMEROUS REGULAR ICE AGES HAVE DOMINATED THE PLANET.
- 134 03:19:45:22 FOR MOST OF THE LAST MILLION YEARS, ICE WAS EARTH'S NORMAL CLIMATE.
- 135 03:19:51:23 AN ICE AGE BEGINS WHEN SUMMER TEMPERATURES FAIL TO MELT A PREVIOUS WINTER'S SNOW.
- 136 03:19:58:06 YEAR AFTER YEAR, THE ICE SHEET GROWS.
- 137 03:20:01:22 ONLY THE TROPICAL CLIMATE NEAR THE EQUATOR CAN STOP ITS ADVANCE.
- 138 03:20:07:08 EVENTUALLY, EARTH MYSTERIOUSLY WARMS UP AND THE ICE BEGINS RETREATING.
- 139 03:20:12:07 WHAT STARTS AN ICE AGE?
- 140 03:20:14:22 NO EARTHBOUND THEORY CAN EXPLAIN THE CAUSES OF DRAMATIC CLIMATIC SHIFTS.
- 141 03:20:20:07 INTRIGUED BY THIS MYSTERY, YUGOSLAVIAN

- MATHEMATICIAN MILUTIN MILANKOVITCH SOUGHT TO DEVELOP AN ASTRONOMICAL THEORY THAT WOULD ACCOUNT FOR ICE AGES.
- 142 03:20:30:22 HE BELIEVED THEY WERE CAUSED BY CHANGES IN THE EARTH'S RELATIONSHIP TO THE SUN.
- 143 03:20:40:19 WE KNOW THAT THE SEASONS ARE CAUSED BY THE EARTH TILTING ON ITS AXIS, BUT EVERY 41,000 YEARS, THE EARTH'S TILT VARIES BY A FEW DEGREES.
- 144 03:20:55:19 EVERY 100,000 YEARS, EARTH'S ORBIT VARIES FROM NEARLY CIRCULAR TO ELLIPTICAL, MOVING THE EARTH MILLIONS OF MILES FURTHER FROM THE SUN.
- 145 03:21:10:22 EARTH WOBBLER SLOWLY LIKE A TOP IN SPACE TO COMPLETE A CIRCLE ABOUT EVERY 20,000 YEARS.
- 146 03:21:18:20 THE TILT, STRETCH, AND WOBBLE OF EARTH'S ORBIT CHANGE THE DISTRIBUTION OF ENERGY FROM THE SUN.
- 147 03:21:26:07 MILANKOVITCH CALCULATED THAT THESE CHANGES COULD TRIGGER THE ICE AGES.
- 148 03:21:31:07 WITHOUT SUPPORTING EVIDENCE, HIS THEORY WAS FORGOTTEN UNTIL A SERENDIPITOUS DISCOVERY IN THE CARIBBEAN ISLAND OF BARBADOS.
- 149 03:21:39:22 AT FIRST, SCIENTISTS WERE PUZZLED BY THE ISLAND'S TERRACES THAT LOOKED LIKE GIANT STAIRSTEPS.
- 150 03:21:46:23 EVENTUALLY, THEY DETERMINED THE TERRACES WERE ACTUALLY ANCIENT BEACHES BECAUSE THEY CONTAINED FOSSILS OF CORAL LIKE THOSE STILL FOUND ALONG THE SHORE OF BARBADOS TODAY.
- 151 03:22:01:00 SINCE CORAL GROWS ONLY IN SHALLOW WATER, THE TERRACES SUGGEST SEA LEVEL WAS ONCE HIGHER.
- 152 03:22:08:08 COULD THE TERRACES REFLECT A TIME WHEN SEA LEVEL ROSE AS THE LAND ICE MELTED?
- 153 03:22:15:27 WHEN THE FOSSIL BEACHES WERE DATED, THEY APPEARED TO MATCH THE ASTRONOMICAL CYCLE SUGGESTED BY MILANKOVITCH -- A CLUE ADDING

ONE MORE PIECE TO THE CLIMATE PUZZLE.

- 154 03:22:29:28 AFTER WORLD WAR II, SCIENTISTS STARTED A GLOBAL SEARCH FOR THE REMAINS OF PAST CLIMATES ON THE OCEAN FLOOR.
- 155 03:22:39:03 A PISTON CORER IS PLUNGED THROUGH THE OCEAN INTO THE MUDS ALONG THE BOTTOM.
- 156 03:22:55:18 THE EXPLORERS WOULD DISCOVER THE SEDIMENTS ON THE SEAFLOOR HELD A RECORD OF THE GREAT ICE SHEETS ON LAND.
- 157 03:23:12:25 IN THE LABORATORY, SEA CORES ARE UNWRAPPED -- TIME CAPSULES FROM AN ANCIENT EARTH.
- 158 03:23:20:13 WHEN THE CORE IS DISSECTED, NEARLY A HALF MILLION YEARS OF EARTH'S CLIMATE HISTORY IS REVEALED.
- 159 03:23:36:14 AT THE LAMONT DOHERTY GEOLOGICAL OBSERVATORY AT COLUMBIA UNIVERSITY, THOUSANDS OF CORES FROM AROUND THE WORLD ARE CATALOGUED AND STORED.
- 160 03:23:47:10 THEY CREATE AN UNRIVALED LIBRARY OF THE PAST.
- 161 03:23:55:11 GEOLOGIST JAMES HAYS HAS PIONEERED IN SEA CORE ANALYSIS.
- 162 03:23:59:17 INTERPRETATION OF THESE ANCIENT RECORDS IS A MILESTONE IN CLIMATE SCIENCE.
- 163 03:24:07:09 ALTHOUGH THE FACT THAT ICE AGES HAD ONCE OCCURRED WAS FIRST REALIZED FROM STUDYING THE GEOLOGY OF CONTINENTAL SURFACES, CONTINENTS DON'T CONTAIN A GOOD RECORD OF THE SEQUENCE OF ADVANCES AND RETREATS OF THE GREAT ICE SHEETS.
- 164 03:24:25:24 THE CONTINENT SURFACES ARE ALWAYS BEING WORN AWAY, EITHER BY ABRASION OF THE GREAT ICE SHEETS OR BY RAIN, RIVERS, AND WIND.
- 165 03:24:36:23 THE PARTICLES WASHED FROM THE CONTINENTS EVENTUALLY END UP IN MUDS ON THE OCEAN FLOOR, SUCH AS THIS CORE.

- 166 03:24:46:07 THESE CORES, IN CONTRAST TO THE FRAGMENTED RECORD OF THE CONTINENTS, CONTAIN A COMPLETE RECORD OF LONG PERIODS OF TIME.
- 167 03:24:58:25 THEY ALSO CONTAIN FOSSIL REMAINS OF ORGANISMS THAT THRIVED IN ANCIENT SEAS.
- 168 03:25:05:09 WHEN THEY DIED, THEIR SHELLS RAINED DOWN TO BECOME THE SEDIMENTS ON THE OCEAN BOTTOM.
- 169 03:25:12:29 LAYER UPON LAYER, THESE SHELLS FORM A VAST RECORD OF CHANGING CLIMATE.
- 170 03:25:18:14 THE FOSSILS OF ANCIENT MARINE LIFE ARE CAREFULLY EXTRACTED FROM THE CORES.
- 171 03:25:24:10 AS THESE TINY, GLASSLIKE SHELLS ARE SORTED AND ORGANIZED, THEY BEGIN TO TELL A STORY.
- 172 03:25:33:29 THESE ARE THE SHELLS OF MICROSCOPIC ORGANISMS KNOWN AS RADIOLARIA.
- 173 03:25:39:06 WHEN LIVING, THESE CREATURES ARE DELICATELY ADAPTED TO TEMPERATURE AND CHEMISTRY OF THE WATER.
- 174 03:25:45:28 AS CLIMATE CHANGES AND THE TEMPERATURE OF THE OCEAN WATER CHANGES, DIFFERENT SPECIES ARE FAVORED AND FLOURISH.
- 175 03:25:55:20 THE DISTRIBUTION OF RADIOLARIA IS LINKED TO CHANGES IN SEAWATER TEMPERATURE.
- 176 03:26:01:21 BY CHARTING TEMPERATURE CHANGES, HAYS AND HIS COLLEAGUES FOUND A CYCLE MATCHING THE ONE SUGGESTED BY MILANKOVITCH.
- 177 03:26:10:19 EACH OCEAN CORE CAN BE VIEWED AS A MONITORING STATION CAREFULLY RECORDING CHANGES IN THE OCEAN WATER THAT LIES ABOVE IT.
- 178 03:26:20:25 WITH CORES FROM AROUND THE WORLD, WE RECONSTRUCT GLOBAL CHANGES IN THE OCEAN THAT ACCOMPANY ICE-AGE CYCLES.
- 179 03:26:29:09 BY MAPPING THE GLOBAL TEMPERATURE OF ANCIENT SEAS AND CONNECTING THEM WITH CYCLES IN SPACE, RESEARCHERS HAVE MOVED CLOSER TO

SOLVING THE ICE-AGE PUZZLE.

- 180 03:26:40:15 AN INGENIOUS METHOD OF ANALYSIS REVEALED STILL ANOTHER MATCHING CYCLE.
- 181 03:26:46:07 IN ADDITION TO TEMPERATURE, THE OCEAN'S CHEMISTRY ALSO CHANGES DURING AN ICE AGE.
- 182 03:26:53:07 SHELLS AND MARINE ORGANISMS RECORD THIS CHANGE.
- 183 03:26:56:23 BY COMPARING THEM THROUGH ISOTOPE ANALYSIS, HAYS CAN DETERMINE WHEN THE ICE AGES OCCURRED.
- 184 03:27:06:24 WHEN THE CYCLES OF CHANGE IN TEMPERATURE AND CHEMISTRY WERE PLOTTED, IT WAS DISCOVERED THAT BOTH CYCLES MATCHED THOSE PREDICTED BY MILANKOVITCH.
- 185 03:27:20:24 CHANGES IN THE GEOMETRY OF EARTH'S ORBIT ARE THE PACEMAKERS OF THE ICE AGES.
- 186 03:27:28:10 NEW YORK'S HUDSON RIVER IS A STRIKING EXAMPLE OF THE RECURRING PHENOMENON.
- 187 03:27:34:09 JAMES HAYS.
- 188 03:27:35:24 15,000 TO 17,000 YEARS AGO, THIS VALLEY WAS FILLED WITH A RIVER OF ICE.
- 189 03:27:42:22 IT DRAINED THE GREAT NORTH AMERICAN ICE SHEET, WHICH WAS RAPIDLY RETREATING TO THE NORTH.
- 190 03:27:50:25 WILL THE ICE ONE DAY RETURN TO THIS VALLEY?
- 191 03:27:55:06 THE ANSWER IS YES.
- 192 03:27:57:07 JUST AS THE CHANGE OF THE SEASONS ARE CONTROLLED BY THE GEOMETRY OF EARTH'S ORBIT AROUND THE SUN, SO ALSO ARE ICE AGES.
- 193 03:28:08:24 AS FALL WILL CHANGE TO WINTER, INEVITABLY, THE ICE WILL RETURN TO THIS VALLEY.
- 194 03:28:15:00 IF HAYS AND HIS COLLEAGUES ARE RIGHT, PLANET EARTH MAY FACE ANOTHER ICE AGE WHICH COULD REACH ITS PEAK SOME 100,000 YEARS FROM NOW.

- 195 03:28:32:09 800 MILES FROM THE SOUTH POLE IS VOSTOK, ONE OF SEVERAL RESEARCH STATIONS MANNED BY THE SOVIET UNION IN ANTARCTICA.
- 196 03:28:41:27 VOSTOK, WHICH HAS RECORDED THE COLDEST TEMPERATURE ON EARTH, SITS ON THE ANTARCTIC ICE SHEET'S THICKEST PART.
- 197 03:28:50:18 THE ARRIVAL OF AN AMERICAN TRANSPORT IS A RARE SIGHT.
- 198 03:28:56:13 THIS ONE HAS BROUGHT FRENCH GLACIOLOGIST CLAUDE LORIOUS HERE TO SHARE IN THE CELEBRATION OF AN HISTORIC EVENT.
- 199 03:29:06:08 [SPEAKING RUSSIAN] IN 1979, THE SOVIETS BEGAN AN AMBITIOUS PROJECT -- TO DRILL THROUGH THE 2 1/2-MILE-THICK ANTARCTIC ICE SHEET.
- 200 03:29:29:25 THE TECHNIQUE OF DRILLING POLAR ICE WAS FIRST DEVELOPED HERE IN GREENLAND.
- 201 03:29:35:24 THE ICE CONTAINS A LITANY OF ENDLESS SEASONS AS LAYERS OF SNOWFALL ARE COMPRESSED OVER TENS OF THOUSANDS OF YEARS.
- 202 03:29:45:22 FROM THE ICE CORES, SCIENTISTS HOPE TO LEARN MORE ABOUT THE CLIMATE THAT HAS RULED PLANET EARTH FOR MOST OF THE LAST MILLION YEARS.
- 203 03:29:57:18 THE MILE-LONG VOSTOK CORE IS UNIQUE.
- 204 03:30:00:22 IT CONTAINS 150,000 YEARS OF HISTORY -- FROM THE BEGINNING TO THE END OF THE LAST ICE AGE.
- 205 03:30:08:08 CLAUDE LORIOUS WILL SPEND THE NEXT THREE MONTHS CAREFULLY SECTIONING AND PREPARING THE CORE FOR SHIPMENT TO FRANCE.
- 206 03:30:17:21 AT THE INSTITUTE OF GLACIOLOGY IN GRENOBLE, HE WILL BEGIN THE PAINSTAKING ANALYSIS.
- 207 03:30:30:21 *BONJOUR* .
- 208 03:30:32:27 THE VOSTOK CORE HAS SURVIVED A LONG JOURNEY, YET EVEN HERE IT REMAINS EXTREMELY FRAGILE.
- 209 03:30:40:21 EVEN THE SLIGHTEST ALTERATION CAN DESTROY ITS

UNIQUE VALUE.

- 210 03:30:45:20 TO SAFEGUARD THE CORE, THE LABORATORY IS STERILIZED AND MAINTAINED AT TEMPERATURES BELOW FREEZING.
- 211 03:30:53:05 TO ELIMINATE CONTAMINATION, ONLY THE CORE'S HEART IS USED.
- 212 03:31:01:07 EACH LAYER IS LIKE THE PAGE OF A DIARY.
- 213 03:31:05:22 A MERE SLIVER REVEALS NEW DETAIL.
- 214 03:31:08:19 TRAPPED IN THE ICE IS DUST AND ASH, A CLUE TO LONG-DEAD VOLCANOES.
- 215 03:31:16:08 MORE INTRIGUING ARE BUBBLES OF GAS, WHIFFS OF ANCIENT AIR.
- 216 03:31:21:07 SEEN UNDER POLARIZED LIGHT, THE ICE BECOMES A KALEIDOSCOPE OF COLOR AND FORM.
- 217 03:31:28:08 AMONG THESE TINY CRYSTALS IS ALL THAT IS NEEDED TO DETERMINE THE ATMOSPHERE'S TEMPERATURES AND CHEMISTRY DURING THE LAST ICE AGE.
- 218 03:31:40:27 ONE PROVOCATIVE FIND IS A RECORD OF ATMOSPHERIC CARBON DIOXIDE.
- 219 03:31:46:09 CORING HAS CONFIRMED THAT THE CARBON DIOXIDE LEVEL DURING THE LAST ICE AGE WAS LOWER THAN TODAY.
- 220 03:31:54:17 HOW IT GOT THAT WAY IS STILL UNKNOWN.
- 221 03:31:58:18 FOR CLAUDE LORIUS, THERE IS URGENCY TO THE SEARCH.
- 222 03:32:02:28 IF WE WANT TO UNDERSTAND CURRENT CHANGE OF TERRESTRIAL ENVIRONMENT AND EVENTUALLY BE ABLE TO PREDICT FUTURE CONDITIONS, I THINK IT IS FIRST VERY IMPORTANT TO ESTABLISH WHAT WERE THE PAST CHANGES AND SEE IF WE ARE ABLE TO EXPLAIN THEM.
- 223 03:32:23:24 I THINK THIS IS A NECESSITY IF WE WANT TO MAKE PROJECTIONS INTO THE FUTURE.

- 224 03:32:37:28 ALTHOUGH THE ADVANCE AND RETREAT OF ICE SEEMS INEVITABLE, EARTH'S CLIMATE HAS REMAINED SURPRISINGLY TEMPERATE OVER BILLIONS OF YEARS.
- 225 03:32:49:22 NOW SCIENTISTS HAVE UNCOVERED ANOTHER PARADOX.
- 226 03:32:53:09 IF APPEARS OUR ANCIENT SUN WAS ONCE SMALLER AND RADIATED LESS HEAT THAN IT DOES TODAY.
- 227 03:33:01:12 IF THE SUN WAS FAINT, SNOW WOULD GRADUALLY ACCUMULATE AND THE PLANET GROW COLDER AND COLDER.
- 228 03:33:09:10 EVENTUALLY, THE OCEANS WOULD FREEZE, AND EARTH WOULD BECOME A GLISTENING PLANET OF ICE.
- 229 03:33:16:24 BUT THERE IS NO SUCH EVIDENCE FOR THIS SCENARIO.
- 230 03:33:21:07 LIQUID WATER, THE BASIS OF LIFE, HAS EXISTED ON EARTH FOR NEARLY ALL OF ITS HISTORY.
- 231 03:33:31:01 A CLUE TO THE MYSTERY CAN BE FOUND MILLIONS OF MILES FROM PLANET EARTH.
- 232 03:33:37:21 PROBES TO VENUS AND MARS DISCOVERED ATMOSPHERES FIERCE AND ALIEN TO OUR OWN.
- 233 03:33:43:26 VENUS IS HOT AND NOXIOUS.
- 234 03:33:47:20 NEARLY 900 DEGREES FAHRENHEIT AT ITS SURFACE, ITS ROCKS GLOW RED.
- 235 03:33:56:06 THIS HOTHOUSE CLIMATE EXISTS BECAUSE THE THICK ACID CLOUDS CONTAIN AN EXTRAORDINARY AMOUNT OF CARBON DIOXIDE.
- 236 03:34:07:09 LIKE THE GLASS OF A GREENHOUSE, CARBON DIOXIDE TRAPS HEAT AND PREVENTS IT FROM ESCAPING BACK INTO SPACE.
- 237 03:34:16:24 THE ATMOSPHERE OF VENUS CONTAINS 300,000 TIMES MORE CARBON DIOXIDE THAN PLANET EARTH.
- 238 03:34:27:29 IF, LONG AGO, VENUS HAD LIQUID WATER, IT BOILED

- AWAY INTO THIS HELLISH WORLD'S ATMOSPHERE.
- 239 03:34:36:22 AT THE OPPOSITE EXTREME IS MARS, A FROZEN PLANET.
- 240 03:34:41:09 A LAND OF MASSIVE VOLCANOES, ITS LANDSCAPE IS TESTIMONY TO THE VIOLENT ACTIVITY THAT ONCE MAY HAVE PUMPED ENOUGH CARBON DIOXIDE INTO ITS ATMOSPHERE TO WARM THE PLANET.
- 241 03:34:56:05 MARS' SCOURED SURFACE SUGGESTS IT WAS ONCE WARM ENOUGH FOR LIQUID WATER TO FORGE DEEP CANYONS AND RIVER VALLEYS AND TO CARVE GREAT FLOOD PLAINS.
- 242 03:35:10:10 BUT SOMEHOW MARS LOST ITS ANCIENT ATMOSPHERE.
- 243 03:35:13:19 ITS LIQUID WATER DISAPPEARED.
- 244 03:35:15:19 WHAT REMAINS IS A FROZEN, DECIMATED WORLD.
- 245 03:35:24:08 IF VENUS IS A HOTHOUSE THAT CANNOT COOL DOWN, MARS IS A WORLD THAT CANNOT WARM UP -- EXTREME WORLDS OF FIRE AND ICE.
- 246 03:35:38:22 IN ORBIT BETWEEN VENUS AND MARS IS EARTH.
- 247 03:35:42:22 NEITHER TOO HOT NOR TOO COLD, ITS ATMOSPHERE HAS JUST THE RIGHT AMOUNT OF CARBON DIOXIDE FOR LIFE TO FLOURISH.
- 248 03:35:52:22 UNLIKE VENUS AND MARS, THE EARTH'S SURFACE IS CONSTANTLY CHANGING, SCOURED BY WIND AND WATER AND TORN APART BY POWERFUL FORCES WITHIN.
- 249 03:36:06:25 CARBON STORED IN THE EARTH IS CONTINUALLY RECYCLED THROUGH THE LAND, OCEANS, AND THE ATMOSPHERE.
- 250 03:36:14:09 EVEN LIFE PLAYS A ROLE IN THE CYCLE.
- 251 03:36:18:10 THIS DYNAMIC PROCESS HELPS CONTROL THE AMOUNT OF CARBON DIOXIDE IN EARTH'S ATMOSPHERE AND SEEMINGLY RESOLVES OUR ANCIENT SUN'S MYSTERY.

- 252 03:36:27:24 IF THERE WAS MORE CARBON DIOXIDE IN OUR EARLY ATMOSPHERE, IT COULD HAVE TRAPPED ENOUGH HEAT TO KEEP THE PLANET WARM.
- 253 03:36:37:22 SCIENTISTS BELIEVE THAT ABRUPT CHANGES IN CARBON DIOXIDE CAN CAUSE ABRUPT CLIMATIC SHIFTS, EVEN INFLUENCE ICE AGES.
- 254 03:36:46:07 AND, LIKE VENUS AND MARS, CREATE RADICALLY DIFFERENT WORLDS.
- 255 03:36:51:19 THIS UNDERSTANDING OF CARBON DIOXIDE'S ROLE IS A GREAT MODERN SCIENTIFIC INSIGHT.
- 256 03:36:57:11 THERE'S A NEW URGENCY TO UNDERSTAND CARBON DIOXIDE'S ROLE IN THE LIFE OF PLANET EARTH.
- 257 03:37:05:21 SINCE CIVILIZATION'S ADVENT, PARTICULARLY IN THE INDUSTRIAL AGE, MAN HAS INJECTED ENORMOUS AMOUNTS OF CARBON DIOXIDE INTO THE ATMOSPHERE BY THE BURNING OF COAL, OIL, AND GAS.
- 258 03:37:19:08 SLASH-AND-BURN DEFORESTATION TO CREATE FARMS RELEASES MORE CARBON DIOXIDE.
- 259 03:37:25:20 A TIME BOMB SEEMS TO BE TICKING IN OUR ATMOSPHERE.
- 260 03:37:32:15 EARTH'S CLIMATE IS MAINTAINED ONLY WHEN THE SOLAR ENERGY ABSORBED BY THE PLANET EQUALS THE AMOUNT RETURNED TO SPACE.
- 261 03:37:41:21 AS CARBON DIOXIDE INCREASES, IT RETARDS THE ESCAPE OF ENERGY.
- 262 03:37:46:21 LIKE A GREENHOUSE, EARTH'S LOWER ATMOSPHERE HEATS UP.
- 263 03:37:53:08 HAWAII'S MAUNA LOA OBSERVATORY IS AN IDEAL LABORATORY FOR SAMPLING THE EARTH'S ATMOSPHERE.
- 264 03:38:00:09 HERE IN 1958, CHARLES KEELING OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY DEVELOPED A METHOD FOR MEASURING CARBON DIOXIDE.
- 265 03:38:10:24 SINCE THEN, CARBON DIOXIDE HAS RISEN SOME 9%.

- 266 03:38:15:24 AT THIS RATE, IT COULD DOUBLE SOMETIME IN THE NEXT CENTURY AND RAISE THE MEAN TEMPERATURE OF EARTH SOME 3-10 DEGREES FAHRENHEIT.
- 267 03:38:28:23 SUCH GLOBAL WARMING COULD LEAD TO THE MOST DRAMATIC CHANGE IN EARTH'S CLIMATE SINCE THE LAST ICE AGE, A CHANGE FAR GREATER THAN ANY EXPERIENCED BY MANKIND.
- 268 03:38:42:08 PREDICTIONS ARE FIERCELY DEBATED, BUT ALL AGREE WE ARE PERFORMING A GREAT EXPERIMENT ON OURSELVES AND OUR PLANET.
- 269 03:38:53:21 THE RESULTS OF A POTENTIAL CARBON DIOXIDE WARMING MAY EVENTUALLY BE SEEN HERE.
- 270 03:39:01:02 SINCE THE INTERNATIONAL GEOPHYSICAL YEAR IN 1958, ANTARCTICA HAS BECOME A NATURAL LABORATORY WHERE THE DYNAMICS OF ICE ARE EXPLORED BY SCIENTISTS.
- 271 03:39:11:26 HERE, GLOBAL WARMING WOULD CREATE A SPECIAL THREAT.
- 272 03:39:17:02 MOST OF THE ANTARCTIC CONTINENT IS COVERED BY ICE NEARLY 2 MILES THICK.
- 273 03:39:23:09 MUCH OF IT RESTS IN THE OCEAN.
- 274 03:39:26:08 IT IS UNSTABLE AND SUSCEPTIBLE TO MOVEMENT.
- 275 03:39:29:25 SCIENTISTS ARE CONCERNED.
- 276 03:39:31:25 COULD ANTARCTICA LOSE ITS ICE?
- 277 03:39:35:24 THEY EXPLORE EVEN THE SLIGHTEST CHANGE IN THE VAST AND COMPLEX ICE CAP.
- 278 03:39:55:07 THEY MAP CREVASSE FIELDS -- GREAT FROZEN RIVERS THAT SLOWLY BUT STEADILY FLOW INTO THE ROSS ICE SHELF, A FLOATING SLAB THE SIZE OF FRANCE.
- 279 03:40:06:17 THE ROSS ICE SHELF ACTS AS A PLUG, HOLDING BACK THE ICE COVERING WEST ANTARCTICA.
- 280 03:40:16:07 WARMING COULD CAUSE THE SHELF'S LEADING EDGE TO DISINTEGRATE AND DESTROY THE BARRIER THAT

- CONTAINS THE UNSTABLE WEST ANTARCTIC ICE SHEET BEHIND IT.
- 281 03:40:29:06 IF WEST ANTARCTICA'S ICE SHEET MELTS, SEA LEVEL COULD RISE 20 FEET, DRAMATICALLY CHANGING THE GEOGRAPHY OF PLANET EARTH.
- 282 03:40:47:05 VENICE, THE CROWN JEWEL OF THE ADRIATIC.
- 283 03:40:51:09 LATTICED BY CANALS THAT FORM ITS STREETS, VENICE IS OFTEN FLOODED BY STORMS AT HIGH TIDE.
- 284 03:41:03:07 IF CARBON DIOXIDE WERE TO SUBSTANTIALLY WARM THE EARTH, SUCH FLOODING COULD BECOME COMMONPLACE.
- 285 03:41:10:29 EVEN A SMALL INCREASE IN SEA LEVEL COULD CAUSE HAVOC.
- 286 03:41:18:07 STORM SURGES AT UNUSUALLY HIGH TIDE WOULD THREATEN COASTLINES MORE AND MORE FREQUENTLY.
- 287 03:41:25:26 EVENTUALLY, CITIES WOULD NEED DIKES AND BARRIERS LIKE LONDON HAS INSTALLED ACROSS THE THAMES TO PROTECT IT FROM TIDAL SURGES.
- 288 03:41:37:06 BUT POPULOUS COUNTRIES ON COASTAL PLAINS JUST ABOVE SEA LEVEL ARE MOST VULNERABLE.
- 289 03:41:45:03 IN 1970, 300,000 PEOPLE DIED DURING A RAVAGING STORM SURGE IN BANGLADESH.
- 290 03:41:54:28 A WARMER CLIMATE COULD MAKE TEMPERATE REGIONS MUCH DRIER.
- 291 03:42:01:03 THE WORLD'S BREADBASKETS MIGHT SHIFT.
- 292 03:42:03:09 THE SOVIET UNION COULD REPLACE THE AMERICAN MIDWEST AS THE WORLD'S LEADING PRODUCER OF GRAIN.
- 293 03:42:11:08 IN COUNTRIES DEPENDENT ON IRRIGATION, THE WARMING COULD BE DEVASTATING.
- 294 03:42:16:25 HOTTER, DRIER CLIMATES COULD PUT STILL GREATER PRESSURES ON NOW-ARID REGIONS.

- 295 03:42:23:09 DESERT AREAS WOULD EXPAND.
- 296 03:42:25:09 THOSE WHO DEPEND ON RIVERS FOR WATER MAY WELL EXPERIENCE HARDSHIP.
- 297 03:42:31:06 THE COLORADO RIVER, WHICH DELIVERS WATER TO AMERICA'S DESERT STATES, ALREADY LOSES MORE THAN 3/4 OF ITS SUPPLY TO EVAPORATION.
- 298 03:42:41:17 RISING CARBON DIOXIDE WOULD ALSO ACT AS A GLOBAL FERTILIZER FOR GREEN PLANTS.
- 299 03:42:48:13 EXPLOSIVE GROWTH COULD RADICALLY ALTER ECOLOGICAL BALANCES THAT HAVE EVOLVED OVER BILLIONS OF YEARS.
- 300 03:42:55:24 WE KNOW THAT CLIMATE SHAPES LIFE.
- 301 03:42:58:23 WE CAN ONLY GUESS AT THE IMPACT ON LIFE FROM A MAJOR CHANGE IN GLOBAL CLIMATE.
- 302 03:43:05:29 STILL, THERE'S A GREAT UNCERTAINTY ABOUT THE CONSEQUENCES OF A GLOBAL WARMING.
- 303 03:43:11:11 SOME UNDOUBTEDLY WOULD BENEFIT.
- 304 03:43:13:25 OTHERS WOULD SUFFER.
- 305 03:43:15:24 CONSEQUENCES OF WARMING ARE SERIOUS ENOUGH TO BE CONSIDERED THE MOST IMPORTANT CHALLENGE IN MODERN CLIMATE RESEARCH.
- 306 03:43:24:04 AT THE NATIONAL CENTER FOR ATMOSPHERIC RESEARCH IN BOULDER, COLORADO, METEOROLOGIST WARREN WASHINGTON DESIGNS EXPERIMENTS CALLED CLIMATE MODELS THAT SIMULATE THE ATMOSPHERE OF EARTH.
- 307 03:43:37:07 THIS IS ONE OF THE WORLD'S FASTEST COMPUTERS.
- 308 03:43:41:07 IT'S ABLE TO DO 100 MILLION OPERATIONS PER SECOND.
- 309 03:43:45:24 WE DO THINGS WE COULDN'T DO 10 YEARS AGO ON THE COMPUTER.
- 310 03:43:51:26 WE CAN GENERATE A MODEL OF THE ATMOSPHERE THAT SIMULATES WINDS, TEMPERATURES,

- PRESSURES, RAINFALL, SNOW COVER, OVER 23,000 POINTS OVER THE ENTIRE GLOBE.
- 311 03:44:11:09 SIMULATING THE DYNAMICS OF EARTH'S ATMOSPHERE IS A COMPLEX TASK.
- 312 03:44:17:18 THE LAND, OCEANS, POLAR ICE, EVEN LIFE CAN INFLUENCE CLIMATE.
- 313 03:44:22:11 EXTERNAL FACTORS LIKE CHANGES IN RADIATION FROM THE SUN CAN FURTHER COMPLICATE THE MODEL.
- 314 03:44:30:09 THE COMPUTER'S ENORMOUS SPEED MANIPULATES THE MANY CLIMATE FACTORS.
- 315 03:44:35:20 THE SIMULATED EARTH IS RUN FOR A FEW COMPUTER DAYS TO PREDICT WEATHER, OR FOR YEARS TO PREDICT CLIMATE.
- 316 03:44:45:15 BY CHANGING THE CLIMATE MODEL'S FACTORS, THE SCIENTISTS CAN PERFORM TESTS NOT POSSIBLE IN THE REAL WORLD.
- 317 03:44:54:06 THEY EXPLORE THE SCENARIOS THAT MIGHT REVEAL CAUSES OF GLOBAL CLIMATE CHANGE.
- 318 03:45:00:24 CLIMATOLOGIST STEVE SCHNEIDER USES MODELS TO EXPLORE THE POSSIBLE IMPACTS OF A CARBON DIOXIDE WARMING.
- 319 03:45:08:27 WHY DO WE NEED MODELS FOR THE PREDICTION OF CLIMATE?
- 320 03:45:13:25 WE NEED TO ESTIMATE HOW MUCH GREENHOUSE GAS HUMANS ARE PUTTING IN, AND THEN ASK, "WHAT'S THAT GOING TO DO?" WELL, IF YOU HAVEN'T GOT A PHYSICAL MODEL THAT WE CAN POLLUTE TO SEE WHAT HAPPENS, THE ONLY OTHER MODEL WITH ANY HOPE OF TELLING ABOUT THE FUTURE IS A MATHEMATICAL MODEL INSIDE THE COMPUTER.
- 321 03:45:41:25 WE TAKE THIS MODEL AND WE ESSENTIALLY SIMULATE THE PRESENT CLIMATE.
- 322 03:45:47:20 WE THEN ADD GREENHOUSE GASES TO THE MODEL, COMPARE THE TWO, AND HAVE SOME IDEA OF THE FUTURE CLIMATICALLY IF WE DID ADD THOSE GASES.

- 323 03:46:00:24 WHILE SOME SCIENTISTS SPECULATE ON THE FUTURE, OTHERS TEST AN INTRIGUING SCENARIO OF CLIMATE IN THE PAST.
- 324 03:46:09:18 TODAY THIS SEMIARID REGION IS PART OF COLORADO'S PUEBLO RESERVOIR STATE PARK.
- 325 03:46:15:09 WHEN DINOSAURS RULED THE EARTH, IT WAS COVERED IN WATER.
- 326 03:46:19:26 SEARCHING FOR EVIDENCE OF THE ANCIENT SEA IS GEOLOGIST ERIC BARRON.
- 327 03:46:25:24 THESE ROCKS DATE FROM THE CRETACEOUS PERIOD, ABOUT 90 MILLION YEARS AGO.
- 328 03:46:31:09 THESE ROCKS AND FOSSILS SHOW THIS AREA WAS COVERED BY A SHALLOW SEA STRETCHING FROM COLORADO TO KANSAS AND FROM THE GULF OF MEXICO TO THE ARCTIC BASIN.
- 329 03:46:44:01 THE FOSSILS ARE DISTINCTLY MARINE.
- 330 03:46:46:29 THEY INDICATE THAT THE CLIMATE WAS MUCH WARMER THAN TODAY.
- 331 03:46:51:14 IN GREENLAND, WE FIND FOSSIL ALLIGATORS.
- 332 03:46:54:13 UNLESS AN ALLIGATOR HAD FUR, THE CLIMATES MUST HAVE BEEN MUCH WARMER.
- 333 03:47:00:04 FOSSILS IN THE ROCKS TELL OF A PLACE IN SHARP CONTRAST WITH EASTERN COLORADO'S NEAR-DESERT ENVIRONMENT TODAY.
- 334 03:47:09:24 100 MILLION YEARS AGO, DINOSAURS ROAMED HERE IN WHAT MUST HAVE BEEN A LUSH AND TROPICAL WORLD.
- 335 03:47:22:24 AT THE NATIONAL CENTER FOR ATMOSPHERIC RESEARCH, ERIC BARRON USES A COMPUTER MODEL TO FIND OUT WHAT MIGHT HAVE CAUSED SUCH WARMTH IN EARTH'S PAST.
- 336 03:47:38:22 THE POSITION OF THE CONTINENTS IS ADJUSTED TO THE DINOSAURS' TIME.
- 337 03:47:44:07 OTHER CLIMATE FACTORS ARE ADDED TO CREATE AN

- ANCIENT EARTH.
- 338 03:47:48:21 BARRON KNOWS WHAT IT WAS LIKE THEN.
- 339 03:47:52:03 HE MUST FIND OUT WHY.
- 340 03:47:54:07 THE CRETACEOUS GEOGRAPHY STORED IN THIS COMPUTER IS CLEARLY DRAMATICALLY DIFFERENT THAN PRESENT-DAY GEOGRAPHY.
- 341 03:48:02:24 WE SEE AUSTRALIA ATTACHED TO ANTARCTICA, INDIA IN THE SOUTHERN HEMISPHERE, AND THE EVIDENCE FOR FLOODING, FOR INSTANCE, HERE IN NORTH AMERICA.
- 342 03:48:15:24 HIS PRIMARY CLUE CAME FROM A NEW UNDERSTANDING OF THE PLANET'S MOVING CRUST FROM PLATE TECTONICS.
- 343 03:48:24:10 SCIENTISTS HAVE DISCOVERED THAT IN THE MIDDLE OF THE OCEANS IS AN UNDERSEA MOUNTAIN RANGE WHERE A FIERY DRAMA BEGINS THE CREATION OF EARTH'S CRUST.
- 344 03:48:43:07 HOT ROCK FROM THE INTERIOR RISES AND SPREADS THE SEAFLOOR TO EACH SIDE, RESULTING IN THE MOVEMENT OF EARTH'S CONTINENTS.
- 345 03:48:53:06 IT'S HARD TO IMAGINE A MORE DRAMATIC CHANGE IN THE EARTH'S SURFACE.
- 346 03:48:59:19 WHEN WE PLUG IN THIS DRAMATIC CHANGE IN CRETACEOUS GEOGRAPHY INTO A CLIMATE MODEL, WE ACHIEVE ONLY 1/3 OF THE WARMING NECESSARY TO EXPLAIN CRETACEOUS CLIMATES.
- 347 03:49:11:23 WHAT CAUSED MOST OF THE WARMING?
- 348 03:49:14:24 WHERE SEAFLOOR IS CREATED, EXPLORERS IN DEEP-DIVING SUBMERSIBLES HAVE FOUND TOWERING VENTS THAT SPEW GAS AND CARBON DIOXIDE.
- 349 03:49:24:13 GASES FROM THE VENTS EVENTUALLY ESCAPE TO BECOME PART OF THE ATMOSPHERE.
- 350 03:49:34:08 ELSEWHERE, SEAFLOOR IS RECYCLED BACK INTO THE EARTH ALONG THE WORLD'S DEEP OCEAN

TRENCHES.

- 351 03:49:41:07 AS THE SEAFLOOR SINKS INTO THE EARTH'S INTERIOR, IT MELTS.
- 352 03:49:46:07 CARBON LOCKED IN THE EARTH FOR MILLIONS OF YEARS RISES TO THE SURFACE IN VOLCANIC VIOLENCE, ONCE AGAIN ENRICHING THE ATMOSPHERE.
- 353 03:49:56:21 BY INCREASING HIS MODEL'S CARBON DIOXIDE, BARRON CAN ACCOUNT FOR THE EXTREME WARMTH OF THE CRETACEOUS PERIOD.
- 354 03:50:04:21 IF THE MODEL IS ACCURATE, THE ROCKS OF EASTERN COLORADO SHOULD REVEAL WIDESPREAD EVIDENCE OF VOLCANIC ACTIVITY.
- 355 03:50:14:07 WITHIN THESE SAME CRETACEOUS ROCKS, WE FIND THE EVIDENCE FOR INCREASED VOLCANISM THAT WOULD HAVE INCREASED CARBON DIOXIDE LEVELS.
- 356 03:50:23:22 EACH ONE OF THESE YELLOW LAYERS REPRESENTS THE ASH FROM A VOLCANIC ERUPTION.
- 357 03:50:30:04 THERE ARE MULTIPLE LAYERS.
- 358 03:50:32:07 ALL AROUND THE GLOBE, WE FIND SIMILAR EVIDENCE FOR INCREASED VOLCANIC ACTIVITY DURING THE CRETACEOUS.
- 359 03:50:39:10 THE LOCATIONS OF CONTINENTS AND THE FLOODING OF THE CONTINENTS IS ONLY PART OF THE STORY OF EXPLAINING CRETACEOUS WARMTH.
- 360 03:50:49:05 RESULTS FROM CLIMATE MODELS STRONGLY SUGGEST THAT A CO₂ GREENHOUSE EFFECT MAY HAVE PLAYED A MAJOR ROLE IN EXPLAINING THE CRETACEOUS' EXTREME WARMTH.
- 361 03:51:00:07 IF IT'S HAPPENED IN THE PAST, IT CAN HAPPEN AGAIN.
- 362 03:51:05:05 NOW SCIENTISTS HAVE ADDED A NEW CHAPTER TO THE CARBON DIOXIDE STORY.
- 363 03:51:10:07 PAT ZIMMERMAN IS AN ATMOSPHERIC CHEMIST.

- 364 03:51:13:26 HE NOW STUDIES TERMITES.
- 365 03:51:16:01 IN THE WILD, THEIR POPULATIONS REMAIN IN CHECK, BUT ZIMMERMAN BELIEVES THE ACCELERATED CLEARING OF RAIN FORESTS AND GRASSLANDS MAY LEAD TO A POPULATION EXPLOSION.
- 366 03:51:28:05 THERE ALREADY MAY BE 3/4 TON OF TERMITES FOR EVERY HUMAN BEING ON EARTH.
- 367 03:51:35:07 WE THINK GLOBAL TERMITE POPULATIONS COULD BE INCREASING.
- 368 03:51:39:07 AN AREA OF TROPICAL FOREST THE SIZE OF CONNECTICUT IS CLEARED EACH YEAR.
- 369 03:51:45:06 WHEN IT'S CLEARED, THE ECOSYSTEM IS SIMPLIFIED.
- 370 03:51:48:23 THE WHOLE DECOMPOSER CHAIN IS REMOVED.
- 371 03:51:51:22 PREDATORS ARE REMOVED.
- 372 03:51:53:22 THAT ALLOWS TERMITE POPULATIONS TO REALLY EXPLODE.
- 373 03:52:00:24 TERMITES HAVE INHABITED THE EARTH FOR 100 MILLION YEARS.
- 374 03:52:06:18 LONG STUDIED FOR THEIR COMPLEX SOCIAL STRUCTURE, ZIMMERMAN IS NOW MONITORING TERMITES FOR METHANE, ONE OF A NUMBER OF WARMING GASES.
- 375 03:52:17:10 METHANE HAS DOUBLED OVER THE PAST 150 YEARS.
- 376 03:52:21:09 SCIENTISTS ARE CONCERNED ABOUT ITS LONG-RANGE IMPACT.
- 377 03:52:26:18 TO MEASURE THE METHANE TERMITES PRODUCE, THE INSECTS ARE PLACED IN A JAR ALONG WITH WOOD.
- 378 03:52:33:25 AN ATTACHED INSTRUMENT ANALYZES HOW MUCH WOOD IS CONVERTED TO METHANE.
- 379 03:52:39:03 THE TERMITES' FOOD IS CELLULOSE, FOUND IN PLANTS AND TREES.
- 380 03:52:44:20 FEW ANIMALS CAN DIGEST IT, BUT TERMITES HAVE

- EVOLVED ONE OF NATURE'S MOST EFFICIENT SYMBIOTIC RELATIONSHIPS.
- 381 03:52:52:16 IN THEIR DIGESTIVE SYSTEMS ARE MICROBES THAT SECRETE AN ENZYME REDUCING CELLULOSE TO SUGAR.
- 382 03:52:59:10 THE TERMITES THEN ABSORB THE SUGAR.
- 383 03:53:02:24 A BY-PRODUCT OF THIS TRANSFORMATION IS METHANE.
- 384 03:53:07:24 ALTHOUGH THIS EXPERIMENT SEEMS SIMPLE, NOBODY HAD DONE IT BEFORE.
- 385 03:53:13:17 WE KNEW TERMITES EMIT METHANE 50 YEARS AGO, BUT NOBODY HAD THE CAPABILITY TO QUANTITATE THE EMISSION RATE.
- 386 03:53:22:09 NOBODY REALIZED THERE WERE ENOUGH TERMITES SO THAT EMISSION COULD POTENTIALLY AFFECT THE CHEMISTRY OF THE EARTH'S ATMOSPHERE.
- 387 03:53:30:26 THE RESULTS OF ZIMMERMAN'S RESEARCH ARE INTRIGUING.
- 388 03:53:34:09 METHANE IS ALSO ON THE RISE FROM OTHER SOURCES, LIKE SWAMPS AND CATTLE AND THE INCREASING CULTIVATION OF RICE.
- 389 03:53:43:18 BUT METHANE IS ONLY ONE GREENHOUSE GAS.
- 390 03:53:46:18 IF THESE GASES CONTINUE INCREASING, THEY COULD DOUBLE CARBON DIOXIDE'S WARMING EFFECT EARLY IN THE NEXT CENTURY, FASTER AND MORE ALARMING THAN PREVIOUSLY THOUGHT.
- 391 03:54:00:09 ALTHOUGH THIS RESEARCH IS IN ITS INITIAL STAGES, THERE'S NO QUESTION THAT EARTH AND ITS CLIMATE WOULD BE COMPLETELY DIFFERENT IF IT WEREN'T FOR THE ACTIVITIES OF BIOLOGICAL SOURCES.
- 392 03:54:15:09 OUR EARTH IS A DELICATE BALANCE BETWEEN OUR ATMOSPHERE AND OUR BIOSPHERE.
- 393 03:54:21:04 EMISSIONS FROM TERMITES ILLUSTRATE HOW A SINGLE ORGANISM CAN POTENTIALLY AFFECT OUR CLIMATE.

- 394 03:54:32:04 SOMETIME IN THE 1990s, CLIMATE SCIENTISTS EXPECT TO HAVE CONCLUSIVE PROOF WHETHER THE CURRENT WARMING TREND IS LARGER THAN NORMAL FLUCTUATIONS IN CLIMATE.
- 395 03:54:45:01 CLIMATOLOGIST STEVEN SCHNEIDER.
- 396 03:54:47:21 THE CLIMATE SCIENCES FACE A BIG CHALLENGE -- WHEN WILL WE HAVE A GLOBAL UNDERSTANDING OF THE CLIMATE SYSTEM?
- 397 03:54:56:23 HOW WILL IT CHANGE?
- 398 03:54:58:23 THE TROUBLE IS, WE KNOW GREENHOUSE GASES ARE INCREASING AND THAT THEY CAN HAVE A GLOBAL EFFECT.
- 399 03:55:06:23 ENVIRONMENTAL PROBLEMS ARE NOT NEW.
- 400 03:55:09:09 THEY GO BACK CENTURIES.
- 401 03:55:11:10 THE LONDON SMOGS ARE A GOOD EXAMPLE, BUT THEY WERE LOCAL.
- 402 03:55:16:10 ACID RAIN IS ANOTHER EXAMPLE, BUT IT TENDS TO BE REGIONAL.
- 403 03:55:21:09 THE GREENHOUSE EFFECT IS DISTURBING BECAUSE IT IS BOTH GLOBAL AND POTENTIALLY LONG-LASTING.
- 404 03:55:27:10 OUR CLIMATE MODELS GIVE US A CRYSTAL BALL, BUT THEY'RE NOT PERFECT.
- 405 03:55:33:09 THE CRYSTAL BALL IS DIRTY.
- 406 03:55:35:24 HOW LONG DO WE CLEAN THE GLASS BEFORE ACTING ON WHAT'S INSIDE?
- 407 03:55:48:01 FOR THE FIRST TIME, MAN MAY PLAY AN OMINOUS ROLE IN THE FUTURE CLIMATE OF PLANET EARTH.
- 408 03:55:55:14 ALTHOUGH CLIMATE CHANGES SEEM INEVITABLE, THE HUMAN SPECIES IS A MAJOR PLAYER IN THE DRAMA.
- 409 03:56:03:23 NEW TOOLS AND TECHNOLOGY HELP SCIENTISTS ASSEMBLE THE PIECES OF THE CLIMATE PUZZLE.
- 410 03:56:10:25 WE HAVE BEGUN TO UNDERSTAND FACTORS THAT

INFLUENCE THE CLIMATE OF PLANET EARTH.

411 03:56:16:29 WE HAVE UNCOVERED RECORDS OF A SPECTACULAR PAST, REVEALED IN EARTH'S ROCK, ITS OCEANS, THE ICE, AND AIR, AND EVEN ITS LIFE.

412 03:56:31:09 WE HAVE SEEN DEVASTATING ICE AGES TRANSFORM THE EARTH AND TROPICAL CLIMATES IN PLACES NOW FRIGID.

413 03:56:41:11 WE HAVE JOURNEYED INTO SPACE AND FOUND CLUES TO OUR FUTURE.

414 03:56:46:07 COULD EARTH BECOME A WORLD OF FIRE OR ICE?

415 03:56:50:22 A NEW FRONTIER OF EXPLORATION HAS UNCOVERED AN EARTH THAT HAS CHANGED IN THE PAST AND WILL CHANGE IN THE FUTURE.

416 03:57:01:25 HOW MUCH AND WHEN ARE THE QUESTIONS THAT REMAIN IN THE PUZZLE OF EARTH'S CLIMATE.

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