Planet Earth

Fate of the Earth

1	07:01:26:04	*Planet Earth* #107 "Fate of the Earth" Closed captioned
2	07:01:53:18	NARRATOR: In a faraway corner of the South Pacific, scientists are investigating the creation of these curious looking islands and of their destruction by an equally curious force -- life.
3	07:02:13:18	Some four billion years ago, the Earth was a very different place -- hot, turbulent and barren.
4	07:02:26:02	Today, Earth is alive with color.
5	07:02:30:00	What caused this evolution from barren landscape to living planet?
6	07:02:38:06	Along the coast of California, one scientist is exploring the origins of life on Earth, probing the machinery of the very first cells, he makes structures that are windows on the past.
7	07:02:53:23	In Australia's outback, clues in ancient rocks have reset life's evolutionary clock.
8	07:03:00:15	They reveal the face of an early Earth, and creatures that began to make the air we breathe today.
9	07:03:10:18	Deep in the English countryside, a scientist believes it is life that weaves the world around us into an intricate fabric.
10	07:03:19:13	He sees the working of all the world in the simple beauty of flowers.
11	07:03:24:19	Today, our knowledge of planet Earth is growing and so, too, is our immense power of destruction.
12	07:03:37:10	Will the fires of a nuclear holocaust transform this haven in space into a cold and hostile world?
13	07:03:47:01	And will today's images of famine and suffering become a portrait of the future?
14	07:03:55:01	Science has revealed our world as never before.
15	07:03:59:22	And yet, we still face the greatest challenges of all.

16 07:04:03:00 As we change the world at an ever increasing rate, will new discovery and new knowledge bring new wisdom?

17 07:04:11:11 At stake is nothing less than the fate of planet Earth.

18 07:04:57:08 ***WARNING FORMAT ERROR

19 07:05:00:26 *IBM is proud to support the innovative spirit of scientific inquiry that made this series possible* .

20 07:05:10:14 NARRATOR: Amid the blue waters of the coral reef in the Western Pacific live thousands of enchanting creatures.

21 07:05:20:02 In this microcosm of the natural world, there is order, beauty and a sense of harmony.

22 07:05:28:18 For millions of years, it has survived as one of nature's marvels.

23 07:05:34:05 Then, in 1953, man came here to make history.

24 07:05:45:22 You have a grandstand seat here to one of the most momentous events in the history of science.

25 07:05:52:15 In less than a minute, you will see the most powerful explosion ever witnessed by human eyes.

26 07:06:00:25 The flash will come out of the horizon just about there.

27 07:06:04:07 And this is the significance of the moment: This is the first full-scale test of a hydrogen device.

28 07:06:11:28 If the reaction goes, we're in the thermonuclear era.

29 07:06:17:01 MAN: Seven, six, five, four, three, two, one.

30 07:06:33:03 NARRATOR: The first hydrogen bomb obliterated an island and blew a crater a mile wide in the reef.

31 07:06:41:05 Today, we build weapons with many times the power.

32 07:06:46:12 The place is Eniwetok.

33 07:06:50:20 Once, there were 47 islands here.

34 07:06:53:17 Now only 45 remain.

35 07:06:56:19 Amid the rubble, Eniwetok has become a symbol of man's newfound power of destruction.

36 07:07:05:17 Yet, as we have learned to destroy, we have begun to understand and protect our delicate and complex world.

37 07:07:13:25 30 years after the first hydrogen test, scientists return to study what remains.

38 07:07:23:11 Some craters are still contaminated with radioactive waste, but life, although less varied, has returned, a tribute to the planet's great resilience.

39 07:07:37:02 Life plays a central role in the workings of planet Earth.

40 07:07:42:16 As science discovers new connections between Earth's living creatures and its atmosphere, ocean and land, we are gaining a fresh perspective.

41 07:07:52:21 (*bicycle bell ringing*) In the heart of the English countryside lives an intriguing man.

42 07:07:59:20 Jim Lovelock is an atmospheric chemist.

43 07:08:03:22 He is also an unorthodox scientist with an independent turn of mind.

44 07:08:11:19 For the past ten years, he has worked from his private laboratory buried deep in Dedham.

45 07:08:21:22 His poetic vision of the Earth has brought him worldwide recognition.

46 07:08:26:09 LOVELOCK: *Have you ever wondered why the world is such* a lovely place, why the countryside's so pleasant and why the air is so fresh and smells so good and makes you feel good to be out in it?

47 07:08:38:22 Well, I have a theory about it.

48 07:08:40:25 I think that the air and the oceans and the rocks and all living things act together as a single, tightly-coupled system.

49 07:08:50:25 And it's this that really is responsible for the seemliness and the beauty of it all.

50 07:08:56:21 It's just, the whole planet's alive.

51 07:08:59:04 And I've chosen to give that notion the title the Gaia hypothesis.

52 07:09:05:26 And I've chosen the word "Gaia" because that's what the

ancient Greeks called Mother Earth.

53 07:09:11:25 NARRATOR: The goddess Gaia once watched over the ancient world.

54 07:09:15:28 Now we find ourselves the guardians of planet Earth.

55 07:09:19:18 It was not always so.

56 07:09:21:08 Four and a half billion years ago, Earth is a dead planet, its surface battered by a constant rain of asteroids and comets.

57 07:09:33:28 The night is dominated by a stupendous moon.

58 07:09:40:21 A young sun struggles to gather strength.

59 07:09:49:14 Pressures within crack and tear the Earth apart.

60 07:09:54:07 Great volcanoes churn up seas of lava.

61 07:09:58:07 There is no air as we know it.

62 07:10:00:09 There are no continents.

63 07:10:02:14 Not even a final crust has formed.

64 07:10:14:02 Earth seems a world with little promise.

65 07:10:22:07 Yet, even in this alien environment, parts for the elegant machinery of life are assembling.

66 07:10:30:12 After millions of years, the cauldron begins to cool, and something new happens -- it rains.

67 07:10:38:06 (*thunder crashing*) It rains and it rains.

68 07:10:47:23 And as the rains wash nutrients into the oceans, a new force appears on planet Earth.

69 07:10:53:29 Somewhere, perhaps along the margin of new seas, life begins.

70 07:11:01:00 By investigating life's origins, scientists hope to better understand both the evolution and the future course of planet Earth.

71 07:11:12:18 David Deamer is a biologist from the University of California, Davis.

72 07:11:17:13 For him, seashores were the cradles of life.

73 07:11:21:16 DEAMER: Tide pools like this one are just packed with living organisms.

74 07:11:26:22 They're competing for every bit of space available, for the energy and nutrients that are coming in with tides.

75 07:11:34:07 They seem like simple sorts of organisms, and yet, they're the end product of some four billion years of evolution.

76 07:11:41:16 NARRATOR: Even the simplest forms of life are complicated chemical machines made from thousands of intricate molecules.

77 07:11:52:01 DEAMER: There's four major kinds of molecules: nucleic acids carry information; proteins act as catalysts in turning over the cell machinery; carbohydrate is there as an energy source or often as part of the cell's structure; finally, there's lipid, which forms a boundary layer between the inside of the cell and the outside.

78 07:12:15:26 NARRATOR: Floating in the Earth's early seas, organic molecules may have been swept into tide pools and then dried out.

79 07:12:23:13 No one knows for sure how life began.

80 07:12:26:14 But to study how tides could create cells, David Deamer constructs miniature tide pools in his laboratory.

81 07:12:33:25 Into them he puts long ribbon-like molecules called lipids.

82 07:12:38:16 DEAMER: I've got lipid dried here on the microscope by...

83 07:12:42:19 very much under the conditions that you might imagine would occur when some lipid dried out in a tide pool.

84 07:12:48:03 You can see the lipid on this TV monitor.

85 07:12:50:01 It's this amorphous mass over here to the right.

86 07:12:53:12 And I'm going to add a dilute dye solution to the left.

87 07:12:57:08 Here it goes.

88 07:13:00:25 And there you see the water immediately beginning to interact -- long strands begin to form.

89 07:13:09:19 And we'll just pan around on the slide a little bit.

90 07:13:14:16 You can see that the formally amorphous film has now begun to form structures.

91 07:13:23:09 The water is penetrating the dry lipid film and causing the lipid to break up into, uh -- uh-oh, there's a bubble that popped or something -- and, uh, all of these structures are being forced out of the central lipid mass as water adds itself to the molecules.

92 07:13:41:29 NARRATOR: The simple cycle of wetting and drying produces structures very much like the membranes of cells in which other chemicals needed for life could collect.

93 07:13:55:02 Eventually, these structures assembled into intricate cells that could feed, grow and reproduce and life itself began a long journey to transform our planet.

94 07:14:10:10 (*crickets chirping*) But what were the first forms of life like?

95 07:14:22:22 To find out, scientists have traveled to the further parts of the Earth.

96 07:14:33:09 In Northwestern Australia is a region so remote it is called the North Pole -- a place where the rocks are among the oldest on Earth.

97 07:14:44:02 A chance discovery here revealed life's origin to be a full one billion years earlier than anyone had believed.

98 07:14:53:20 Stanley Awramik comes here from the University of California at Santa Barbara.

99 07:14:58:00 I came up to Northwestern Australia to do some fieldwork in banded iron formations.

100 07:15:03:27 After arriving in Port Hedland, I was talking to a local geologist, and he was telling me about some of the sedimentary deposits that were being mined from the early Archean deposits in the North Pole region which was on my way, so I just happened to be driving through here looking for these sedimentary black cherts that I normally collect.

101 07:15:31:06 NARRATOR: For Stan Awramik, it was just another routine collecting trip.

102 07:15:37:10 He was unprepared for the surprise hidden within these

simple rocks.

103 07:15:54:16 Well, the rocks that I just collected here are similar to those that I collected back in 1977 when I was visiting this outcrop for the first time.

104 07:16:03:12 And much to my surprise, when looked under the microscope, on the first thin section I made, I found some very small micron-sized filaments.

105 07:16:13:17 NARRATOR: When the rocks were polished and sliced thin, Awramik was the first to see the very earliest evidence of life.

106 07:16:25:13 Imbedded in the rock were faint outlines of a tiny bacterium three and a half billion years old.

107 07:16:33:01 Its descendants still live on Earth today.

108 07:16:42:23 The coastal waters of Western Australia.

109 07:16:54:24 AWRAMIK: Here in Shark Bay, we have an area unlike any other place on Earth today.

110 07:17:01:11 In the shallow, exposed environments, we see the stromatolites growing that are built by blue-green algae.

111 07:17:08:26 And you can imagine yourself back in time, two billion years ago, this might have been what the shoreline would look like and structures like these, these domes or these columns, would extend way off onto the continental shelves are they existed at the time.

112 07:17:25:16 NARRATOR: At first, the stromatolites look like ordinary boulders.

113 07:17:30:08 In fact, each structure teams with life.

114 07:17:34:04 If we go up here and look at the edge of one of these lumps of rock, we see a greenish color.

115 07:17:42:00 These are photosynthetic blue-green algae.

116 07:17:45:00 And it's organisms like these, in complex communities, that are responsible for building these structures.

117 07:17:52:11 Indeed, even the surface of this rock here -- all blue-green algae.

118 07:17:58:07 The blue-green secrete a little sticky substance around their cells and that sticky substance traps and binds the sediment and the algae grow forming these large dome structures.

119 07:18:11:27 NARRATOR: The emergence of life on Earth altered not only the appearance of the planet but transformed its atmosphere as well.

120 07:18:21:13 Organisms like these invented photosynthesis.

121 07:18:25:19 They removed carbon dioxide from the atmosphere and replaced it with oxygen, enough of it to make animal life possible.

122 07:18:34:15 Some even think that life may be the primary mechanism that keeps the entire planet the way it is.

123 07:18:43:05 The temperatures of Earth have stayed in a range of liquid water -- its oceans have never frozen nor boiled away.

124 07:18:51:25 Could life be the reason why?

125 07:18:57:07 Jim Lovelock believes so.

126 07:19:00:10 In his Gaia hypothesis, he suggests that life itself controls the conditions on planet Earth.

127 07:19:08:08 A scientist who studies atmospheres, Lovelock develops techniques for measuring minute quantities of gases.

128 07:19:18:28 In the 1960s, he was a consultant to NASA as the space agency prepared the Viking Lander to search for life on Mars.

129 07:19:29:07 He began to wonder if the atmosphere on Mars might reveal whether or not there was life on the red planet.

130 07:19:36:01 Life creates highly distinctive gases, but few of these are found on Mars.

131 07:19:42:17 For Lovelock, this suggested a world long dead.

132 07:19:47:10 Unlike Mars, the atmosphere of Earth is brimming with dozens of gases, telltale of life.

133 07:19:54:07 I couldn't help wondering how is that the Earth has such a remarkable atmosphere?

134 07:19:59:24 It's made up of more of gases like the mixture that goes into

the intake manifold of a car, hydrocarbons and oxygen mixed.

135 07:20:07:18 And how can such an extraordinary atmosphere be just right for life?

136 07:20:13:17 And how is it kept at a steady state?

137 07:20:16:19 And then I wondered, maybe we've got it all the wrong way around.

138 07:20:20:25 The air isn't just an environment in which life swims, it is something specifically made by life to keep the environment that it itself wants.

139 07:20:33:15 In other words, the atmosphere, the whole of the Earth, is something made for life for its own purposes.

140 07:20:40:23 And of course, this was the Gaia hypothesis.

141 07:20:44:02 NARRATOR: Could life maintain Earth's peculiar atmosphere and might it have kept the Earth tempered enough to support an abundance of life over the past four and a half billion years?

142 07:20:55:22 Many scientist are skeptical that life plays such a primary role.

143 07:21:00:18 But Lovelock designed a metaphorical world in his computer to explore if it could.

144 07:21:06:11 LOVELOCK: *One of the most serious criticisms of Gaia was made by some biologists,* and it was that there was just no way that natural selection could lead to, um, a global entity like some auntie or trades union that looked after the planet and kept everything right for us.

145 07:21:23:22 NARRATOR: Lovelock imagined a simple world covered by just two kinds of flowers -- dark daisy that grow best when the planet is cool and then warm it up by absorbing the sun's heat; and white ones which take over as the planet warms.

146 07:21:43:04 By reflecting sunlight, they keep the planet cool, just as white clothing is cooler on a hot day.

147 07:21:49:23 Lovelock's computer plays out a scenario.

148 07:21:53:25 The red line shows the increasing energy received from the

sun.

149 07:21:58:21 The task for the flowers is to make the temperature level out.

150 07:22:02:22 At first the temperature rises as dark flowers cover the imaginary planet and warm it up.

151 07:22:09:08 But as white flowers take over, the temperature levels off.

152 07:22:16:11 And just the simple competitive growth of these two daisy specifies is enough to keep the planet beautifully thermostated throughout the whole of its evolutionary history.

153 07:22:26:06 NARRATOR: Though controversial, the Gaia hypothesis is a fascinating idea.

154 07:22:31:23 It draws attention to the contribution of life in the maintenance of planet Earth.

155 07:22:39:00 Earth is a living planet and all its life is enmeshed with global cycles that distribute nutrients through its air, ocean and land.

156 07:22:50:08 (*animals chittering*) From birth to death, plants and animals are linked to these grand geological cycles of the planet.

157 07:23:02:00 (*wind whistling*) Understanding these connections is leading to a radically new view of Earth.

158 07:23:12:06 Michael McElroy is an atmospheric chemist from Harvard University.

159 07:23:17:09 He studies the importance of carbon and other elements in the cycles.

160 07:23:21:25 You know, this-this really is a remarkable place.

161 07:23:24:01 We're standing here on top of a great volcano in Hawaii -- Kilauea -- and observing a scene that in many respects is reminiscent perhaps of what the Earth was like from the beginning.

162 07:23:35:28 We see these hot vents of steam coming out of the interior of the Earth.

163 07:23:41:04 Not just water vapor condensing in the air, but we have carbon dioxide coming out of these vents, we have chlorine

compounds, we have sulfur compounds.

164 07:23:50:08 We're really watching the ingredients that make life, the ingredients that make the atmosphere, the ingredients that make the oceans.

165 07:23:55:19 The carbon atom coming out of this vent today is not on its first time out.

166 07:24:00:23 It was here before.

167 07:24:03:14 That carbon atom perhaps came out four and a half billion years ago, but it has wandered out around the atmosphere and the ocean and the biosphere many times.

168 07:24:09:19 It has been back in the earth perhaps 30 times over its life history, involved in some grand cycles that are absolutely essential to life on this planet.

169 07:24:19:06 NARRATOR: Eruption from a volcano is but the first step in the journey of the carbon atom.

170 07:24:26:06 (*birds chirping*) Now, here we are in a fern forest just a few miles removed from where we were.

171 07:24:41:07 And one can't help but be struck by the incredible difference.

172 07:24:44:17 The luxury of this environment and the barren nature of the landscape that we left.

173 07:24:49:08 This was barren 20 or 30 years ago, and now here we have it.

174 07:24:55:11 The carbon atom is, in some sense, the key to this process with a lot of help from the other key elements that play an essential role, but that carbon atom, if you think about it, comes out of the volcano, it blows around in the air, it goes from the North Pole to the South Pole, it spends about 20 years in the atmosphere before eventually, a growing tree somewhere pulls it out of the air, and within 20 years, it's now a part of a living part of the planet.

175 07:25:21:19 NARRATOR: Eventually, the carbon atom reaches the sea.

176 07:25:24:28 It takes a hundred thousand years before it makes its way to the sediments of the ocean floor.

177 07:25:31:06 Then, for perhaps a hundred million years, it spreads apart

on the plates that carry materials to places where the sea floor descends back into the interior of the earth.

178 07:25:42:07 (*rumbling*) There, the carbon atom is cooked and explosively returned to the atmosphere, where life will use it once more.

179 07:25:56:02 This is a story which has continued over the age of the planet.

180 07:25:59:04 Perhaps 30 times the carbon atom has made this long trip.

181 07:26:01:20 And it's an essential part of the cycling of life-important elements on the Earth.

182 07:26:05:20 NARRATOR: The understanding of these cycles has revolutionized our view of the Earth.

183 07:26:13:18 One of the strangest stories of the Earth's great cycles comes from a tiny atoll in the Western Pacific.

184 07:26:23:02 These islands in Palau emerged millions of years ago when an active volcano reached the ocean's surface.

185 07:26:33:09 Around the margins of the volcano, a coral reef grew.

186 07:26:40:26 Today, it is home to thousands of creatures that form the living tissue of the reef.

187 07:26:57:11 In time, some of the reef was cemented to form limestone rock, and these structures that sprout from the lagoon today.

188 07:27:09:26 These so-called flowerpot islands were literally created by life.

189 07:27:15:12 Yet life is eating them away.

190 07:27:21:20 Every one of these islands is undercut just at the waterline.

191 07:27:26:17 The deep grooves look as though they were made by waves, but the deepest overhangs are on islands in the most sheltered part of the lagoon.

192 07:27:36:00 Erosion helps create these shapes, but another force is also at work.

193 07:27:43:14 On the limestone surface grows a thin veneer of algae that creates an acid that weakens the rock.

194 07:27:53:11 Grazing on the algae are curious creatures called chitons.

195 07:27:58:26 As they eat the algae, they also scrape away the rock.

196 07:28:06:29 The business end of the chiton contains the tools of its trade.

197 07:28:14:13 The scraping is done by the radula, a ribbon of steel-hard teeth that actually eat the rock.

198 07:28:26:20 Surprisingly, the teeth are made from iron, from a mineral called magnetite.

199 07:28:34:01 They are arranged in two neat rows, and as a tooth wears out, a new one takes its place.

200 07:28:43:25 Chitons may appear sleepy, but they are constantly at work making magnetite and chewing away the islands of Palau.

201 07:28:53:03 One day, these islands will be gone, and the delicate dance of biology and geology and chemistry will have come full circle.

202 07:29:07:05 Natural changes like these constantly reshape the Earth.

203 07:29:13:24 But today, the activities of one single species are altering the planet at an ever-increasing rate.

204 07:29:22:03 No place better illustrates the web of life than the tropical rain forests of planet Earth, forests that are under siege.

205 07:29:38:29 (*wood crackling loudly*) 3,000 acres of rain forest will be cleared in the time spent watching this program, cut down for their valuable hardwood and leveled to make room for cattle or crops.

206 07:30:01:04 In 100 years, they may all be gone, and 40% of all living species may vanish with them.

207 07:30:14:24 The rain forests are among the Earth's most complex habitats, where intense competition has ensured only the most ingenious creatures survive.

208 07:30:33:22 The forests are so interconnected, they even create their own weather.

209 07:30:41:15 A satellite image of South America's Amazon basin shows how rain clouds appear and disappear every day.

210 07:30:51:02 They soak the forest.

211 07:30:52:28 Then, the forest returns the moisture to the air to begin the cycle again.

212 07:31:02:03 If the rain forests vanish, so will millions of species, many before we have even discovered them.

213 07:31:10:15 (*wood crackling*) Deep in the Amazon basin, Tom Lovejoy from the United States World Wildlife Fund together with the Brazilian government, has undertaken an ambitious study.

214 07:31:26:18 Lovejoy and his colleagues hope to learn how much of the forest must be saved to preserve the great variety of life within.

215 07:31:37:08 LOVEJOY: The ecosystems are not static at all.

216 07:31:40:07 They are indeed highly dynamic.

217 07:31:42:01 And when they are affected by isolation and fragmentation, all kinds of changes are triggered within them.

218 07:31:49:01 And that is why we are here conducting a giant experiment to really study them as they change and understand what those changes mean for design of reserves.

219 07:32:01:11 It's, uh, in a sense, it's harnessing the forces of destruction to protect the greatest complexity of life of Earth.

220 07:32:11:07 NARRATOR: As the Amazon forest is cut down, experimental sections of different sizes are left intact.

221 07:32:19:03 Over the next 20 years, each will be closely studied in what is perhaps the world's largest laboratory experiment.

222 07:32:31:03 The project starts by identifying the forest's trees.

223 07:32:35:10 (*speaking Portuguese*) A typical forest in North America contains perhaps 60 species of trees.

224 07:32:43:06 This section of forest is alive with at least 600.

225 07:32:47:03 (*man speaking Portuguese*) Each year, deep in the jungle, samples are cut and catalogued by the thousands.

226 07:32:57:21 Often, researchers come across the leaves of a tree they have never seen before, a tree that could contain an unknown enzyme, toxins used to cure disease.

227 07:33:10:15 Rain forests are great living pharmacies.

228 07:33:13:28 Already they have produced drugs valuable in the battle against cancer.

229 07:33:19:18 Here, strains of plants and insects that can improve farming await discovery in the rain forest...

230 07:33:27:09 if they are not destroyed first.

231 07:33:32:18 Ironically, rain forest soils are not rich soils.

232 07:33:36:18 Leveling a rain forest to graze cattle will provide beef, but only for a few years.

233 07:33:42:09 (*horse neighing*) In five years or less, the soil erodes and the forest is gone for generations.

234 07:33:55:13 Everywhere, we are changing our world before we understand how it works, a dangerous experiment upon planet Earth, one that could ultimately destroy one more species: our own.

235 07:34:14:25 August 6, 1945.

236 07:34:17:14 The island of Tinian in the Western Pacific.

237 07:34:20:24 The crew of the *Enola Gay* prepares to depart for Hiroshima.

238 07:34:29:00 (*engine sputtering*) 17 seconds after 8:15 in the morning, they drop the first atomic bomb.

239 07:34:40:00 (*loud explosion*) It explodes with a force of 20,000 tons of TNT.

240 07:34:50:03 The fireball is more than three miles across.

241 07:34:58:04 Near the center, people are vaporized.

242 07:35:01:05 Eyes turned toward the blast instantly melt.

243 07:35:06:27 Within nine seconds, 100,000 people are doomed.

244 07:35:11:22 Three days later, the bomb is used again.

245 07:35:16:14 (*explosion*) This time, the target is Nagasaki.

246 07:35:24:01 The light from the bomb creates permanent shadows burned into wood and etched into steel.

247 07:35:33:09 Ghostly images of what once had been.

248 07:35:38:04 (*wind whipping*) (*baby crying*) Many did not survive for long.

249 07:35:47:20 (*baby crying, indistinct chatter*) Purple spots appear on the skin.

250 07:35:55:27 Hair falls out in handfuls.

251 07:35:59:15 At first, doctors think these are symptoms of a mysterious infectious disease, but it is another effect of the bomb -- radiation sickness.

252 07:36:12:04 It is still claiming victims today.

253 07:36:20:29 Now there are 50,000 nuclear weapons poised for war.

254 07:36:27:25 (*explosion*) And one effect of a nuclear exchange has been overlooked -- accumulative damage by thousands of exploding warheads to Earth's delicately-balanced climate.

255 07:36:40:08 Recently, scientists began to study this new and terrifying problem.

256 07:36:45:02 One of them is Brian Toon.

257 07:36:47:24 This is an incredibly unpleasant thing to consider.

258 07:36:50:09 Uh, my...

259 07:36:51:24 The group that I'm involved with found it be, uh, very difficult to do this work, just because you had to think about what would happen if there were a nuclear war.

260 07:37:00:05 People didn't want to think about it.

261 07:37:01:29 They wanted to shut it out of their minds and not imagine that it would ever happen or could ever happen.

262 07:37:07:16 (*engines humming*) NARRATOR: But a rehearsal for the unthinkable has already been staged in the final months of World War II.

263 07:37:16:12 (*bombs whistling*) Bombing raids over cities like Tokyo and Dresden created great firestorms that raised huge plumes of smoke.

264 07:37:26:16 (*explosions*) Until recently, the importance of smoke had been ignored.

265 07:37:36:01 Brian Toon.

266 07:37:37:22 TOON: *After we'd been considering for several months how dust clouds raised by nuclear weapons* throwing soil into the air might effect the climate, we discovered some work by Paul Crutzen and John Birks which suggested that, uh, massive quantities of smoke might be created *primarily through the burning of forests and wild lands that would be near places that were attacked by weapons* .

267 07:38:01:03 (*wind whistling*) *Now this is very important, because smoke is very powerful in interacting with sunlight* .

268 07:38:07:27 *It's very good at stopping sunlight from reaching the surface* .

269 07:38:11:27 (*rumbling*) NARRATOR: Smoke is the key ingredient in understanding the aftereffects of the first nuclear war.

270 07:38:22:29 (*engine rumbling*) (*explosions*) After the blast, the shockwaves smashes what remains.

271 07:38:38:17 (*explosions*) (*explosion*) Chemical factories and refineries further feed the flames.

272 07:38:51:01 (*explosions*) (*debris clattering)* Huge firestorms whip up great winds and send enormous clouds of smoke miles into the atmosphere.

273 07:39:07:06 (*explosions*) There are enough strategic nuclear weapons in the world to ignite every major city in the northern hemisphere and produce enough smoke to blanket most of the land.

274 07:39:24:26 From high above the North Pole, the first nuclear exchange looks like an eerie display of fireworks.

275 07:39:31:12 Its combined force is 400,000 times greater than the Hiroshima bomb.

276 07:39:40:11 In the days and weeks that follow, clouds of soot enshroud the Earth.

277 07:39:44:28 Temperatures plummet.

278 07:39:47:06 The planet is gripped in a nuclear winter.

279 07:39:50:28 As these smoke clouds move out and prevent sunlight from reaching the surface, temperatures will rapidly begin to drop.

280 07:39:57:28 We already know from our everyday experience that at night time, when there's no sunlight, it gets cold.

281 07:40:04:17 And it would only take a few days for the loss of sunlight at the surface to drop temperatures in the continents to subfreezing temperatures.

282 07:40:14:16 NARRATOR: The nuclear exchange has claimed several hundred million victims.

283 07:40:18:29 Darkness descends at noon, and day becomes eerie twilight.

284 07:40:24:28 (*wind whipping*) Those who do survive face extreme cold.

285 07:40:30:28 (*wind whipping*) Crops and livestock are wiped out, and places that were warm just a few days before are covered in snow and ice.

286 07:40:43:14 This first nuclear winter scenario, based on a simple computer model, has sparked enormous controversy and intense scientific scrutiny.

287 07:40:53:24 At the National Center for Atmospheric Research in Boulder, Colorado, scientists were compelled to take a closer look.

288 07:41:00:15 How accurate was the nuclear winter scenario?

289 07:41:04:05 Steve Schneider is a well known climatologist.

290 07:41:07:01 With a super computer, he creates among the most advanced models of global weather to further analyze nuclear winter.

291 07:41:14:13 His colleague, Curt Covey.

292 07:41:17:22 What we're going to do in our model experiment is tell the model to assume that there is smoke between latitudes 30 degrees and 70 degrees.

293 07:41:28:12 (*computer whirring*) NARRATOR: At the South and North Poles, blue lines indicate subfreezing temperatures.

294 07:41:35:12 Red lines indicate temperatures above freezing.

295 07:41:40:23 (*computer beeps*) The computer simulates the effects of the assumed amount of smoke on Earth's climate.

296 07:41:48:11 Okay, this is day number ten -- ten days after we've assumed the smoke to appear in the middle latitudes.

297 07:41:54:09 We have blue lines in the middle of the continents.

298 07:41:57:08 That means that the freezing has descended.

299 07:42:00:08 In fact, you could look at Eurasia and see that the number in there 243 -- which is in degrees Kelvin.

300 07:42:06:06 That tells you that the temperature has dropped more than 50 degrees Celsius.

301 07:42:09:27 If you'll also look near the coastline -- for example, look at the West Coast of the U.S. -- you'll see that there are no blue lines.

302 07:42:16:02 The warmth of the oceans has prevented the freezing in those coastal areas, so we had good news and bad news, in the sense that it was colder in the middle than the single, one-dimensional result, and warmer in the coasts.

303 07:42:27:24 NARRATOR: But there is a new twist.

304 07:42:29:19 In places, the cold comes sooner than expected.

305 07:42:32:09 (*computer beeps*) This is a case that gave us a bit of a surprise.

306 07:42:36:14 This is only two days after we assumed that the smoke was injected into the atmosphere.

307 07:42:41:26 Despite the short period of time that the smoke is there, there are already little patches of blue, patches of freezing that you can see on that graph that are starting to appear.

308 07:42:51:17 And if that were in the spring or the summer -- the growing season -- it could have devastating effects on crops or other agricultural or even nonagricultural plants.

309 07:43:00:05 (*computer beeps and whirs*) NARRATOR: There is still great uncertainty about nuclear winter.

310 07:43:04:27 Nevertheless, it remains a possible consequence of nuclear war.

311 07:43:11:01 Perhaps most disturbing is the possibility that within weeks, even nations not directly involved in the war could suffer sudden periods of cold and dark.

312 07:43:21:25 They will face a new threat -- famine.

313 07:43:25:01 (*baby crying*) (*wind whipping*) Images from the drought-ridden regions of Africa are all too familiar.

314 07:43:36:16 (*coughing*) Yet even the terrible famine here would be dwarfed in the wake of a nuclear war.

315 07:43:49:08 Bombs could kill one half billion people outright, but for billions more, sudden climate change could wipe out crops worldwide, and starvation would be the fate of the survivors.

316 07:44:03:28 But nuclear war need not be the fate of planet Earth.

317 07:44:07:27 There is evidence that attitudes can change, even in the midst of an arms race.

318 07:44:13:24 (*explosion*) March 1, 1954.

319 07:44:18:19 At its Bikini Island test site in the Pacific Ocean, the United States conducts a secret test of a hydrogen bomb.

320 07:44:26:07 An unexpected chain of events will transform this test into an incident that will change history.

321 07:44:34:24 A small Japanese fishing boat, called the *Lucky Dragon,* accidentally wanders near the test site.

322 07:44:41:19 (*whirring*) Its crew of 23 are covered in atomic ash.

323 07:44:47:24 Doctors discover that all of the crew suffer from radiation poisoning.

324 07:44:52:07 Several are extremely ill.

325 07:44:57:03 One crewman will die.

326 07:44:59:22 (*indistinct chatter*) The poisoning of the 23 men of the *Lucky Dragon* outrages the world, and six years later, the United States and the Soviet Union sign the world's first nuclear test ban treaty.

327 07:45:15:28 Even today, world public opinion among non-nuclear nations can effect the policies of the nuclear powers.

328 07:45:23:17 But even if we avoid nuclear destruction, the inhabitants of planet Earth will face an uncertain future.

329 07:45:35:01 Perhaps the greatest problem facing mankind today is that there may be ten billion of us straining every system on the planet by the year 2050.

330 07:45:46:07 India alone has 12 million more mouths to feed each year.

331 07:45:51:17 Yet, even here, there is hope.

332 07:45:55:23 Until 20 years ago, agriculture in India had barely changed in a thousand years.

333 07:46:02:25 With an explosive increase in population, widespread starvation seemed inevitable.

334 07:46:11:03 Today, India has been transformed.

335 07:46:17:02 The poor are still very poor, but for now there is enough food to go around.

336 07:46:23:09 India has become a net exporter of grain, as production of wheat and rice has boomed.

337 07:46:33:17 This remarkable turnaround began in places of scientific research.

338 07:46:38:23 The International Rice Research Institute in the Philippines.

339 07:46:46:02 25 years ago, scientists here set out to attack world hunger by breeding new, more productive strains of rice.

340 07:46:54:29 In the process, the institute's success became a symbol of the power of science to serve society.

341 07:47:05:03 Dr. M.S. Swaminathan, the institute's director, remembers how desperate the situation appeared when attempts to breed a better rice began.

342 07:47:15:13 After World War II, suddenly many developing countries, which became newly independent, witnessed a population explosion, thanks to the advances in antibiotics and preventive medicine.

343 07:47:29:00 And the food production was stagnant, population growth was fast and it was practically in most fear of doom.

344 07:47:37:25 And there were many learned books saying that many countries cannot feed themselves, my own being one.

345 07:47:43:17 India, it was stated, can never feed itself, and therefore should be written off.

346 07:47:50:05 NARRATOR: The heart of the institute's operation is its enormous seed bank.

347 07:47:54:22 Rice collected all over the globe is brought here and carefully stored.

348 07:48:02:24 There are over 70,000 different varieties here -- the largest collection of rice varieties on Earth.

349 07:48:15:29 In this vast store are the genes for tomorrow's crops, rices that will mature more quickly or grow on more marginal land.

350 07:48:26:05 From the seeds housed here, part of the green revolution grew.

351 07:48:33:17 Scientists realized that traditional rice plants were too slender and tall to support a heavy crop.

352 07:48:40:06 In 1962, they dusted pollen from a Chinese dwarf rice plant onto the panicles of a tall, vigorous variety from Indonesia.

353 07:48:51:14 Four years later, they released the first short, stiff-strawed progeny of that cross.

354 07:48:57:11 A new quest to eradicate world hunger had begun.

355 07:49:05:12 In the years that followed, new rices spread rapidly across southeast Asia.

356 07:49:10:27 Fields that once yielded a single ton of rice per hectare now yielded five.

357 07:49:20:26 The population has increased as rice production has grown.

358 07:49:23:18 With great effort, science is keeping pace.

359 07:49:26:22 But the problem of getting food to the poorest remains.

360 07:49:34:11 As of today, 300 million tons of food grains are lying in various stores of countries, developed and developing.

361 07:49:42:12 At the same time, 400 million people will go to bed hungry tonight.

362 07:49:46:29 We have to solve this larger problem.

363 07:49:49:12 NARRATOR: The work of the International Rice Research Institute approaches a global problem one step at a time.

364 07:49:57:24 Other global problems require new tools.

365 07:50:01:12 Today, the Earth is surrounded by a string of satellites, flung

aloft to study the planet below.

366 07:50:08:21 The unveil a picture of oceans and climate, land and life -- the interconnected fabric of planet Earth.

367 07:50:19:07 At the Goddard Space Flight Center near Baltimore, Maryland, Jim Tucker enhances weather satellite images with computers.

368 07:50:28:19 He assembles a series of global pictures that document the growth of plant life on Earth, information central to understanding how planet Earth operates.

369 07:50:42:26 With satellite data, for the first time, we are able to look at the distribution of vegetation over the entire terrestrial surface, and how this relates to phenomena such as the carbon dioxide concentration in the atmosphere, the advancement or the contraction in the size of deserts, the extent of tropical forests, and also as it relates to the continued habitability of the planet.

370 07:51:10:06 NARRATOR: Like a special lens, Tucker's images reveal the status of plants and trees on Earth at any given time.

371 07:51:19:04 Different colors represent varying degrees of photosynthetic activity.

372 07:51:24:03 The purple of the Amazon rain forest shows the richness of the vegetation.

373 07:51:31:03 The tan of the Sahara reflects a barren desert.

374 07:51:35:04 Tucker has captured the Earth breathing.

375 07:51:38:05 Which each changing season, plants grow and recede.

376 07:51:44:10 Here we have some data from the month of April of 1982.

377 07:51:49:27 At this time in April, there is not that much green vegetation in North America.

378 07:51:56:08 Areas in the southern portion of the U.S., as well as on the West Coast are actively growing.

379 07:52:03:08 And in areas further north, there's no green vegetation present at this time of year.

380 07:52:09:03 If we look in June, now our summer has come.

381 07:52:15:16 And the vegetation is actively growing in the eastern portion of North America, as we see by the red and purple colors.

382 07:52:22:28 Summer has now come to areas of Canada and to Alaska.

383 07:52:29:09 NARRATOR: Although the project is only five years old, Tucker and his colleagues are beginning to make some revealing observations.

384 07:52:36:28 A portrait of drought emerges.

385 07:52:42:04 TUCKER: One of the areas we've been studying in more detail has been western Africa and the boundary between the Sahara desert and the vegetated areas to the south.

386 07:52:52:10 NARRATOR: If the Sahara is on the move, the satellite and the computer will record its march, and time will tell the tale.

387 07:53:01:27 TUCKER: 1984 has been reported to have been one of the driest years on record this century across the entire Sahelian region.

388 07:53:10:29 1985 is somewhat wetter than 1984.

389 07:53:17:19 If we have satellite data such as these, over a ten or 15 year period, then we can start to answer the question: Is the Sahara desert expanding or is it contracting?

390 07:53:29:01 And if so, by how much?

391 07:53:32:03 NARRATOR: We have developed new ways to see our planet at a fortunate time.

392 07:53:37:05 Today, we face the most pressing problems in human history.

393 07:53:45:02 We are in a race with ourselves.

394 07:53:48:16 Can we use our new knowledge to live with our planet, or will we destroy it?

395 07:53:55:01 There are reasons for optimism, for we stand on the threshold of a revolution in the understanding of planet Earth.

396 07:54:03:24 Harvard University's Michael McElroy.

397 07:54:06:14 We live at a unique time in the history of our planet.

398 07:54:10:15 For the first time, one species, man, has now the capacity to change the environment for life on a global scale -- from pole to pole, from the heights of the stratosphere to the depths of the ocean.

399 07:54:22:06 And we're doing it really basically with two causes.

400 07:54:25:14 One, we have come to rely on fossil fuel, on coal, on oil, on natural gas to fuel our ever increasing demand for energy.

401 07:54:34:16 The second, we've come to harness the bounty of the solid part of the planet for purposes of agriculture, to produce food to satisfy the ever increasing demand of a growing population.

402 07:54:48:01 But we have also, at the same time, developed the capacity to think about what we do, to observe the subtle changes and interactions that occur between the ocean, the biosphere and the atmosphere.

403 07:54:59:25 Our challenge now is to apply our knowledge and wisdom to chart a wise course to the future, to live in harmony with our planet, while maintaining the quality of life for all of the living things on this planet.

404 07:55:16:23 NARRATOR: The challenge belongs not only to science, but to each and every citizen of planet Earth.

405 07:55:30:14 We live in an extraordinary age of exploration.

406 07:55:35:05 With new tools and technologies, science has revealed a unique and dynamic Earth.

407 07:55:40:24 We have viewed our extraordinary world from space and from the deep of its oceans.

408 07:55:48:17 We have probed its fiery furnace and have come to know the forces that crack the sea floor and move the continents.

409 07:56:03:19 We have unlocked secrets in the ice and in the rock and found an ancient Earth that has changed many times.

410 07:56:13:11 (*rumbling*) Exotic images have revealed the awesome power of the single star that fuels our planet.

411 07:56:26:23 And in our visits to strange, new worlds, we have unraveled secrets of our own.

412 07:56:34:12 Our knowledge grows at an ever accelerating rate.

413 07:56:39:15 In the last 30 years, we have learned more about planet Earth than in the past 3,000.

414 07:56:46:04 Yet, before us lies the challenge of a new era -- to truly comprehend the world in which we live.

415 07:56:56:05 Our search is echoed in the words of T.S. Eliot.

416 07:56:59:20 "We shall not cease from exploration "and the end of all our exploring "will be to arrive where we started and know the place for the first time."

417 07:59:01:13 *For information about this and other Annenberg Media programs, call: and visit us at:*