

2050 CE: NOAH, WHERE ARE YOU WHEN WE NEED YOU?

P.S. DON'T FORGET YOUR ARK.

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SEVERAL YEARS AGO, IN THE COURSE OF TEACHING AN ADULT CLASS AT A LOCAL CHURCH, I DECIDED IT WAS TIME FOR A LITTLE TEST. SO I ASKED THE CLASS TO RAISE THEIR HANDS AS SOON AS THEY COULD IDENTIFY THE SOURCE OF MY READING. WITH THAT, I BEGAN READING OF A GREAT FLOOD, LASTING 40 DAYS AND 40 NIGHTS, IN WHICH A SINGLE MAN BUILT A GREAT ARK FOR HIS FAMILY AND FOR TWO OF THE MANY ANIMALS ON EARTH. BY THIS TIME, EVERY HAND WAS UP. THEY COULD CERTAINLY IDENTIFY NOAH, TAKEN FROM THE BOOK OF GENESIS, THE FIRST BOOK OF THE OLD TESTAMENT.

BUT THEY WERE MISTAKEN, FOR I WAS READING FROM "THE EPIC OF GILGAMESH," THE STORY OF A FAMOUS HERO OF THE BABYLONIANS, WRITTEN DURING THE FIRST HALF OF THE THIRD MILLENNIUM BCE, SOME 2,000 YEARS BEFORE THE WRITING OF GENESIS. THIS IS NOT TO SAY THAT THE STORY OF NOAH WAS TAKEN FROM THE EPIC OF GILGAMESH. IN ALL PROBABILITY, THEY WERE TAKEN FROM A COMMON AND UNKNOWN SOURCE.

WHAT IS OF PARTICULAR INTEREST IS THE OVERWHELMING FEAR OF PEOPLE SINCE THE BIRTH OF CIVILIZATION AND WRITING, THAT IT WAS

FLOODS THAT WOULD DO THEM IN. TODAY, THOUSANDS OF YEARS LATER, FLOODS REMAIN THE SINGLE WORST CONSEQUENCE OF THE WARMING OF THE WORLDWIDE CLIMATE. FOR THE RISE OF THE WORLD OCEAN, COMMONLY THOUGHT OF AS A RISE IN SEA LEVEL, HAS ALREADY BEGUN. BENJAMIN SANTER, A CLIMATE PHYSICIST AT THE LAWRENCE LIVERMORE NATIONAL LAB IN CA, RECENTLY EMPHASIZED, "SEA LEVEL RISE IS THE THING THAT I'M MOST CONCERNED ABOUT AS A SCIENTIST."

OBSERVATIONS FROM THE PAST 130 YEARS REVEAL GLOBAL MEAN SEA LEVEL RISING BY AN AVERAGE OF 1.7 MM/YR AND BY 3 MM/YR (ALMOST DOUBLE) OVER JUST THE PAST 20 YEARS. ALL PROJECTIONS AGREE THAT THIS RISE WILL CONTINUE AS THE CLIMATE WARMS, PARTLY BECAUSE OF INCREASING OCEAN VOLUME DUE TO THE MELTING OF GLACIERS AND ICE SHEETS, AND PARTLY FROM THERMAL EXPANSION OF THE WORLD OCEAN. LIKE EVERYTHING ELSE, WATER, WHEN IT IS HEATED, EXPANDS.

HOW MUCH OF AN INCREASE IN TEMPERATURE IS REQUIRED TO MAKE A SUBSTANTIAL DIFFERENCE IN CLIMATE CHANGE IN THE BIOSPHERE? JUST A FRACTION OF A SINGLE DEGREE WILL DO IT, BECAUSE OF THE HUGE BODY OF WATER, SOME 72% OF EARTH'S SURFACE, THAT IS INVOLVED. WE NOW KNOW THAT IF MOUNT EVEREST WERE TO BEGIN AT THE BOTTOM OF THE PACIFIC TRENCH, THE OCEAN WOULD TOP THE MOUNTAIN'S SUMMIT BY MORE THAN 1,000 FEET.

DURING THE PALEOZOIC PERIOD, FROM ABOUT 542 TO 251 MA, SOME 172 INDIVIDUAL EVENTS HAVE BEEN RECORDED, EACH LASTING ABOUT 3

MILLION YEARS, AND VARYING IN MAGNITUDE BETWEEN 30 METERS AND 125 METERS. CLOSER TO OUR TIME. DURING THE INTERGLACIAL PERIOD OF THE HOLOCENE, FROM 127 KA TO 111 KA, EARTH'S CLIMATE WAS WARMER, AND GLOBAL AVERAGE SEA LEVEL WAS 4 TO 6 METERS HIGHER. RECENT RESEARCH REVEALS THAT THE MELTING OF BOTH THE ANTARCTIC AND GREENLAND ICE SHEETS CONTRIBUTED SUBSTANTIALLY.

AGAIN, YOU MIGHT WELL ASK, DOES ONE MEASURE OF SEA LEVEL RISE ACCOMMODATE ALL THE WORLD OCEAN? NOT AT ALL. INDEED, IT VARIES WITH DIRECTIONS AND LOCATIONS. SEVERAL FACTORS DETERMINE THE RISE, INCLUDING OCEAN CIRCULATION, TEMPERATURE, SALINITY, REDISTRIBUTION OF THE MASS DUE TO MELTING ICE SHEETS, AND THE REDISTRIBUTION OF GROUND WATER UNDER THE TERRESTRIAL SURFACE. FINALLY, WE MUST CONSIDER CHANGES IN THE SHAPE AND ROTATION OF THE EARTH. THUS, ONE REGION WITH RISING SEA LEVEL, SUCH AS THE NORTHEAST COAST OF THE U.S., IS CURRENTLY RISING 3 TO 4 TIMES AS FAST AS THE WORLDWIDE AVERAGE. THIS RISE ALSO CORRELATES WITH THE RATE OF MELTING OF THE GREENLAND ICE SHEET, IN CONCERT WITH THE SLOWING OF THE DEEP CIRCULATION IN THE ATLANTIC OCEAN. IT ALSO CORRELATES WITH THE 145 KM³ OF GROUNDWATER, ITSELF ACCOUNTING FOR ABOUT 13% IN SEA LEVEL RISE. PROJECTIONS MADE FOR GLOBAL SEA LEVEL RISE BY THE END OF THIS

CENTURY RANGE FROM 20 CM (8 INCHES) TO AS MUCH AS 2 METERS (6.5 FEET).

AGAIN, YOU MIGHT WELL ASK JUST HOW DEVASTATING WOULD A HALF-TO-ONE METER RISE IN SEA LEVEL BE WORLDWIDE? TO BEGIN TO ANSWER THIS, WE MUST BE AWARE THAT MORE THAN HALF THE WORLD'S 7.5 BILLION PEOPLE LIVE IN COASTAL PORTS. FURTHERMORE, THE GREAT MAJORITY OF CLIMATOLOGISTS CREATE THEIR COASTAL MAPS BASED ON DATA FROM THE U.S. GEOLOGICAL SURVEY. SOME PROJECT THIS RISE HAPPENING WITHIN 50 YEARS, OTHERS IN 100 YEARS, AND STILL OTHERS IN 150 YEARS. BUT THEY ALL AGREE THAT IT WILL HAPPEN. IT IS ONLY A MATTER OF A FEW YEARS.

IF SEA LEVEL RISE DURING THE CRETACEOUS ERA WAS BETWEEN 175 AND 325 METERS HIGHER THAN TODAY, A RISE OF A SINGLE METER SEEMS ALMOST INSIGNIFICANT. YET A FEDERAL STUDY WAS MADE IN 2008 OF ROADS, PORTS, AND RAILS ON AN 80 KM-WIDE STRIP ALONG THE GULF COAST FROM MOBILE, AL. TO HOUSTON, TX, HOME TO ABOUT 10 MILLION PEOPLE. IT REVEALED THAT WE COULD EXPECT A SEA LEVEL RISE OF 122 CM - ABOUT 4 FEET, OVER THE NEXT 50-100 YEARS WITH CALAMITOUS RESULTS. THESE INCLUDE A PERMANENT FLOODING OF ABOUT A THIRD OF THE MAJOR ROADS, A TEMPORARY FLOODING OF OTHER MAJOR ROADS AND 29 AIRPORTS, ESPECIALLY DURING MAJOR STORMS. IT WOULD ALSO PUT AT RISK 72% OF THE PORTS, AND A BUCKLING OF RAIL LINES WITH AS LITTLE RISE IN TEMPERATURE AS 1-2° C. BY 2050.

MOVING FROM THE GULF COAST TO THE WEST COAST, AND PARTICULARLY THE SAN FRANCISCO BAY AREA, WHAT WOULD BE THE EFFECT OF A RISE IN SEA LEVEL OF 140 CM (ABOUT 55 INCHES) BY THE END OF THE CENTURY? ALREADY THE SEA LEVEL IS 20 TO 30 CM (ABOUT 10 INCHES) HIGHER THAN A CENTURY AGO. WITH STORM-SPONSORING EL NINO SYSTEMS INEVITABLE, A STORM THAT COINCIDES WITH HIGH TIDES COULD WREAK CATASTROPHE BY THE END OF THE CENTURY. IT WOULD INUNDATE THE LOW-LYING AREAS, INCLUDING BOTH AIRPORTS AT SAN FRANCISCO AND OAKLAND, AND INVOLVE MORE DAMAGE THAN DID THE SAN FRANCISCO EARTHQUAKE OF 1906.

AS FOR FLORIDA, AND PARTICULARLY THE KEYS, A BEST-CASE SCENARIO OF ONLY 7 INCHES BY 2100 WOULD WIPE OUT \$11 BILLION IN PROPERTY DAMAGE, WHILE A WORST-CASE SCENARIO OF THE SEA RISING 55 INCHES BY 2100, WOULD COST UPWARDS OF \$35 BILLION JUST IN PROPERTY LOSSES.

IT IS WHEN WE MOVE OUR SCENARIOS TO NEW YORK CITY THAT WE CONFRONT LOSSES THAT DWARF THE PRECEDING. AN EXHIBIT AT THE MUSEUM OF FINE ARTS HIGHLIGHTS THE IMPACT OF CLIMATE CHANGE BY 2080. HERE, IT PREDICTS, THERE COULD BE A RISE IN SEA LEVEL OF 60 CM OR ABOUT 2 FEET. THIS WOULD BE ACCOMPANIED BY MORE FREQUENT AND MORE INTENSE STORM SURGES ALONG MANHATTAN'S WATERFRONT. AS MANY AS 136 MODERATE FLOODING EVENTS WOULD INUNDATE MANY WASTEWATER PLANTS LOCATED IN THE FLOOD PLAINS.

IN ADDITION, NEWARK, LA GUARDIA, AND KENNEDY AIRPORTS WOULD ALL BE INUNDATED BY FLOOD SURGES SUCH AS INUNDATED NEW ORLEANS WITHIN THE LAST DECADE.

A RECENT WAKEUP CALL OCCURRED IN DECEMBER, 2012, WHEN “SUPERSTORM” SANDY ROARED UP THE NORTHEAST COAST AND INTO NEW YORK CITY AND NEW JERSEY, KILLING MORE THAN 125 PEOPLE, INUNDATING SUBWAYS, CUTTING OFF ELECTRICITY TO MILLIONS, DEVASTATING HOUSES ALONG WITH MANY OTHER BUILDINGS, AND DESTROYING ONE BOARDWALK AFTER ANOTHER. AT THE END OF 2012, THE TOTAL COST WAS TALLIED AT \$60 BILLION.

IT IS, HOWEVER, WHEN WE CONSIDER THE REST OF THE WORLD, ESPECIALLY THE POORER NATIONS, THAT WE FIND CALAMITY BECOMING CATASTROPHE. FOR THE SHEER IMMENSITY OF THE LOSS DUE TO RISING SEA LEVELS, THERE IS NO COUNTRY MORE AT RISK THAN THE 150 MILLIONS WHO MAKE BANGLADESH THEIR HOME. ALREADY THIS IMPOVERISHED NATION HAS SUFFERED MULTIPLE CATASTROPHES SINCE IT WAS PARTITIONED FROM INDIA, THEN AGAIN FROM PAKISTAN IN 1971. THIS RESULTED IN MILLIONS OF WAR DEATHS, APART FROM RUINED BUILDINGS AND INFRASTRUCTURE THAT, AFTER MORE THAN 40 YEARS, REMAIN IN RUINS. TO COMPOUND ITS MISERY, THIS NATION HAS BEEN AFFLICTED BY PERIODIC CIVIL UNREST DUE LARGELY TO ABOMINABLE WORKING CONDITIONS. THIS WAS HIGHLIGHTED RECENTLY BY THE

COLLAPSE OF A HUGE GARMENT FACTORY, KILLING MORE THAN 1100 PEOPLE, MOSTLY WOMEN, FURTHER IMPOVERISHING ITS MAJOR SOURCE OF FOREIGN EXCHANGE. THIS ATOP 500 BOMBS EXPLODING ALMOST SIMULTANEOUSLY IN AUGUST, 2005, PROBABLY BY THE PAKISTANIS. ALL ALONG, THE NATION'S DRINKING WATER HAS BEEN POISONED WITH CYANIDE FROM ITS POLLUTED WELLS. SOME IDEA OF WHAT FURTHER CATASTROPHES LIE AHEAD WAS SEEN IN JULY, 2007, WHEN 2 SEVERE FLOODS AND A CYCLONE CUT RICE PRODUCTION BY 10% - AND 50% IN SOME AREAS. THIS FORCED LONG LINES FOR GOVERNMENT HANDOUTS IN SOME PLACES, AND SPARKED FOOD RIOTS IN OTHER PLACES. IRONICALLY, THIS OCCURRED DESPITE THE TRIPLING OF RICE PRODUCTION AS A RESULT OF THE GREEN REVOLUTION.

ALL OF THIS COLLECTIVE MISERY OVER MORE THAN 40 YEARS WILL PALE NEXT TO THE DEVASTATION THAT WILL ACCOMPANY THE RISING SEAS THAT THREATEN TO INUNDATE UP TO A THIRD OF THE COUNTRY. THERE IS FURTHER IRONY IN THAT FARMERS IN NORTHWESTERN BANGLADESH HAVE EXPERIENCED ONLY HALF THE USUAL WINTER RAINFALL OVER THE PAST HALF CENTURY, MAKING IT IMPOSSIBLE TO PLANT WINTER CROPS. WORSE, RIVERS THROUGHOUT THE NATION ARE INCREASINGLY SALINE AND THUS NO LONGER SUITABLE FOR AGRICULTURE. ALL THIS TOO IN A COUNTRY THAT MUST INCREASE ITS AGRICULTURAL YIELDS BY 40% BY 2050 JUST TO FEED ITS GROWING POPULATION.

WILL BANGLADESH, “NATURE’S LAB FOR NATURAL DISASTERS,” FULFILL ITS DREAM OF BECOMING A GLOBAL SHOWCASE FOR CLIMATE CHANGE? THAT WILL DEPEND ON HOW SUCCESSFUL IT WILL BE IN INTRODUCING SEVERAL AMELIORATION STRATEGIES PROPOSED IN 2009.

1. TO ESTABLISH SEVERAL ENGINEERING PROJECTS TO CONTROL FLOODING AND PROTECT FARMLAND FROM ENCROACHING SEAWATER, SUCH AS THE DUTCH HAVE DONE.
2. TO TEST FOR CROPS THAT BETTER TOLERATE BOTH FLOODS AND DROUGHTS.
3. TO CONCENTRATE ON USING ONCE-BARREN LAND WITH FERTILIZER AND SEED TO GROW VEGETABLES.
4. TO UNDERTAKE MORE COMMUNITY-BASED PROJECTS TO GIRD THE PEOPLE FOR CLIMATE SHIFTS.

THERE CAN BE NO DOUBT THAT THE RICHEST NATIONS, SUCH AS THE U.S. AND THE POOREST NATIONS SUCH AS BANGLADESH, AND ALL THOSE ALMOST 200 NATIONS IN BETWEEN, HAVE THEIR WORK CUT OUT FOR THEM TO COPE WITH THE CLIMATE WARMING OCCURRING ACROSS THE WORLD.

AS WE HAVE NOTED, THE MELTING OF THE GLACIERS AND ICE SHEETS CONTRIBUTE SUBSTANTIALLY TO CLIMATE WARMING. THE MELTING OF THE POLAR ICE SHEETS CONSTITUTES A WILD CARD. PART OF THE REASON FOR THIS IS THAT THE ACCURATE REPRESENTATION OF ICE SHEET

RESPONSE AND ICE-OCEAN INTERACTION IN MODELS CAN ONLY BE APPROXIMATED, LEAVING CONSIDERABLE UNCERTAINTY AS TO THEIR PROJECTIONS. RESEARCH HAS REVEALED THAT AN UNSTABLE RETREAT OF THE WEST ANTARCTIC ICE SHEET (WAIS) MAY OCCUR IF THE PART THAT OVERLIES THE SUBMARINE BASINS IS UNGROUNDED AND MOVES TO A NEW POSITION DOWN A NEGATIVE SLOPE. NO NUMERICAL DEMONSTRATION EXISTS THAT A RUNAWAY INSTABILITY IN THE WAIS HAS BEGUN BUT, ONCE STARTED, IT CAN'T BE STOPPED UNTIL A NEW STABLE POSITION HAS BEEN FOUND.

OF ONE THING SCIENTISTS CAN BE CERTAIN; IF THE WAIS WERE TO MELT COMPLETELY, THE SCALE OF INCREASE IN WORLD OCEAN LEVELS WOULD BE ENORMOUS. AFTER ALL, JUST A SINGLE GIGATON EQUALS 10^9 TONS. THIS IS EQUIVALENT TO THE MASS SHOWERED ON EARTH BY THE IMPACT OF SOME 3,000 H ALLEY-SIZED COMETS. AND THIS COULD BE COMPLICATED BY THE FACT THAT THE GREENLAND ICE SHEET (GIS), THOUGH LACKING THE UNSTABLE CONFIGURATION OF THE WAIS, APPEARS TO BE LOSING AS MUCH MASS - OR MORE - THAN THE WAIS. IN ADDITION, THE GIS NEEDS ONLY HALF THE MASS LOSS RATE OF THE WAIS TO EXERT AN EQUIVALENT EFFECT. THIS IS BECAUSE THE GIS IS CLOSER TO THE NORTH POLE THAN IS THE WAIS TO THE SOUTH POLE.

THERE ARE ADDITIONAL UNCERTAINTIES THAT ADD TO THE OVERALL WILD CARD POSED BY BOTH ICE SHEETS.

1. THE DEEP OCEAN HEAT UPTAKE.

2. THE SNOWFALL ON ANTARCTICA.
3. THE OCEAN CIRCULATION BENEATH THE ICE SHELVES, RESULTING IN BASAL MELTING.
4. GLACIAL AND ICE SHEET RESPONSE.
5. IMPROPER SCALING CONTRIBUTION FROM TERRESTRIAL WATER STORAGE AND NON-CLIMATE CHANGE-RELATED GLACIER AND ICE-SHEET LOSS.
6. LACK OF ACCOUNTING FOR REDUCED OCEAN HEAT UPTAKE AND REDUCED GLACIER CONTRIBUTIONS FROM THE REDUCED AREA.
7. A LACK OF SUFFICIENT INFORMATION ON REGIONAL VARIATIONS.

TWO OF THE CONSEQUENCES OF SEA-ICE DECLINE ARE THE LOSS OF HABITAT FOR SEA-ICE ALGAE AND SUB-ICE ALGAE PHYTOPLANKTON. TOGETHER, THESE TWO ACCOUNT FOR 57% OF THE TOTAL ANNUAL PRIMARY PRODUCTION IN THE ARCTIC OCEAN, CRITICAL TO THE RELEASE OF ORGANIC MATERIAL THAT FUELS THE ARCTIC MARINE FOOD WEB. BY INCREASING THE ANNUAL MELT SEASON BY 20 DAYS OVER THE PAST 3 DECADES, IT HAS CEATED MISMATCHES IN THE TIMING OF ZOOPLANKTON PRODUCTION AND THAT OF THE ARTIC COD THAT FEED ON THEM AS WELL AS THEIR SEABIRD AND MARINE MAMMALIAN PREDATORS. EVEN MORE OMINOUS IS THE LOSS OF SEA-ICE IN EXACERBATING THE MELTING PERMAFROST IN UP TO 1,500 KM INLAND FROM THE COAST.

THE IPCC HAS ADDRESSED THIS CONCERN OF MELTING SEA-ICE BY

IMPOSING AN EVEN MORE DRASTIC TIME TABLE. IF CO₂ EMISSIONS CONTINUE ON THEIR CURRENT SHARP RISE, THE ARCTIC OCEAN WILL BE MOSTLY ICE-FREE IN SUMMER BEFORE MID-CENTURY, 50 YEARS EARLIER THAN THE 2007 FORECAST. FORTUNATELY, THERE ARE STEPS THAT CAN STILL BE TAKEN TO ADVANCE SEA-LEVEL PROTECTIONS. THESE INCLUDE A GREATER UNDERSTANDING OF BOTH THE DYNAMICAL INTERACTIONS BETWEEN ICE SHEETS AND THE WORLD OCEAN, AND OF THE WORLD OCEAN'S RESPONSE TO CLIMATE CHANGE. THEY ALSO INCLUDE QUANTIFYING CHANGES IN PRECIPITATION OVER ANTARCTICA, AND A CONTINUAL MONITORING OF ONGOING CHANGES.

A FINAL OMINOUS NOTE. RECENT CORRECTIONS IN MEASURING SEA LEVEL RISE POINT TO A SPEEDING UP RATHER THAN A SLOWING DOWN. THERE CAN BE NO FURTHER DITHERING. NO FURTHER DISMAL DENIALS BY POLITICIANS WHO SHOULD HAVE BEEN CRACKING ON THIS AT LEAST 20 YEARS AGO. OUR CHILDREN AND THEIRS AFTER THEM ARE COUNTING ON US.