

Climate Change

WHAT IS IT?

WHERE IS IT GOING?

AND HOW DO WE KNOW?

CHAPTER 9

**Greenland
Becoming Greener**

THIS IS GREENLAND

GREENLAND IS A LAND MASS ABOUT 80% COVERED WITH AN ICE SHEET THAT AVERAGES ABOUT 1.3 MILES IN THICKNESS AND NEARLY 2 MILES AT ITS MAXIMUM THICKNESS. IT IS ONE OF TWO SUCH ICE SHEETS ON EARTH, THE OTHER ONE BEING IN ANTARCTICA.

THE INTERIOR IS COLD (AND DARK IN THE WINTER) WITH TEMPERATURES DOWN TO THE MINUS 70'S F. BUT A FEW CRAZY SCIENTISTS INHABIT IT SOMETIMES. THE INTERIOR SELDOM IF EVER REACHES THE MELTING TEMPERATURE OF THE ICE.



[Greenland entry](#) in the CIA World Factbook.

A [NASA Description](#) of the Greenland (and Antarctic) Ice,

And [another one](#) from a British risk management center serving the insurance industry.

THIS IS GREENLAND

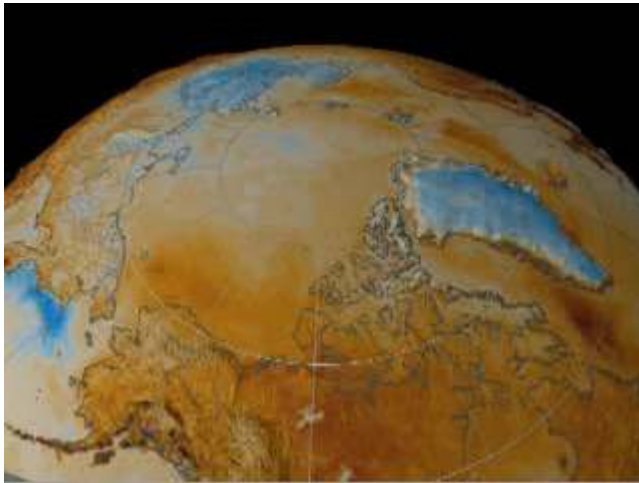
IT IS A DIFFERENT STORY AROUND THE EDGE, WHERE TEMPERATURES IN THE SUMMER CAN EASILY REACH 40 DEGREES FAHRENHEIT, WHICH IS WELL ABOVE THE MELTING POINT.

THERE ARE A NUMBER OF TOWNS ALONG THE COAST, ESPECIALLY THE WARMER WEST COAST — EVEN NORTH OF THE ARCTIC CIRCLE.



Travel web sites often give current climate data. [Here is one](#) that describes Greenland's climate.

THESE ARE SOME NASA IMAGES OF ARCTIC TEMPERATURE CHANGES DURING RECENT YEARS. YOU CAN SEE THAT THE GREENLAND INCREASES HAVE BEEN AROUND THE EDGE. A LARGE MASS OF ICE SUCH AS THE ONE IN THE INTERIOR CAN RESIST TEMPERATURE CHANGES.



The orange and red colors represent an increase of 0 to 0.4 (0.72°F) degrees C, while the blue colors represent a decrease of 0 to 0.4 (0.72°F) degrees. Each color step indicates a change of 0.02 degrees Celsius.

**These images are part of a video that you can access at the following link:
http://www.nasa.gov/centers/goddard/mpg/97509main_AllSeasonTrend.mpg**

THIS NASA ARTICLE TELLS ABOUT EXPERIMENTS WITH A LASER ALTIMETER* TO MEASURE THE THICKNESS OF GREENLAND'S ICE. THIS SHOWS HOW THERE IS MELTING AROUND THE EDGES AND A SLIGHT THICKENING OF THE ICE IN THE INTERIOR OF GREENLAND.

THE THICKENING IS NOT NEARLY ENOUGH TO MAKE UP FOR THE LOSS OF ICE AROUND THE EDGES. SO THERE IS A NET LOSS OF ICE FROM GREENLAND.

HERE IS A LINK TO THE ARTICLE:

<http://svs.gsfc.nasa.gov/stories/greenland/index.html>

*** THE LASER ALTIMETER USED A BEAM OF LASER LIGHT FROM AN AIRPLANE TO MEASURE THE HEIGHT OF THE GROUND (OR ICE) BELOW. SEE THE NEXT SLIDE.**

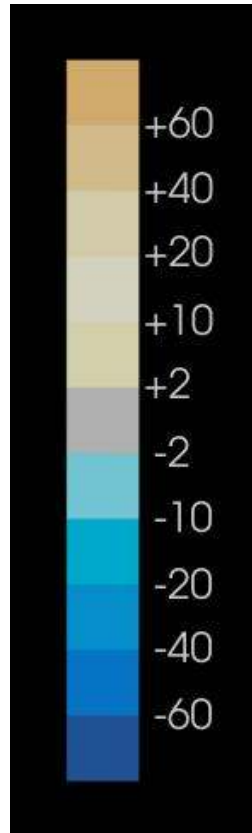
**MORE RECENTLY, LASER
RANGING FROM
AIRPLANES HAS BEEN
USED TO DETERMINE THE
HEIGHT OF THE ICE AND
SNOW.**



**THIS IMAGE FROM
CHAPTER 7
ILLUSTRATED LASER
ALTIMETRY. THE TIME IT
TAKES FOR THE LIGHT
BEAM TO REACH THE ICE
AND RETURN TO THE
PLANE GIVES THE
HEIGHT OF THE ICE
ASSUMING, OF COURSE,
THAT THE POSITION OF
THE PLANE IS KNOWN.**

(IT IS.)

THIS IMAGE IS FROM THE ARTICLE FROM 2 SLIDES AGO. THE BLUE AREAS ARE LOSING ICE. THE LIGHT GRAY AREAS ARE GAINING, AND THE DARK GRAY AREAS NEITHER GAINING NOR LOSING.



THE AREAS OF LOSS ARE AROUND THE EDGES WHERE THE TEMPERATURE IS INCREASING.

HOW THE COLORS REPRESENT THE LOSS OF THICKNESS OF THE ICE SHEET IN CENTIMETERS PER YEAR



SOURCE: <http://svs.gsfc.nasa.gov/stories/greenland/index.html>



IT IS GOING TO TAKE A LONG TIME TO MELT ALL OF THIS GREENLAND ICE. BUT IT IS MELTING, AND THERE ARE STUDIES THAT SAY THE RATE IS INCREASING.

HERE IS A RESEARCH PAPER QUOTED IN THE SECOND GLACIER CHAPTER, CHAPTER 7. IT WAS PUBLISHED IN SCIENCE MAGAZINE RECENTLY. IT IS

Glaciers Dominate Eustatic Sea-Level Rise in the 21st Century, by Meier et. Al., SCIENCE, Vol 317, Aug., 24, 2007, Pg. 1064

DON'T WORRY ABOUT THAT WORD "EUSTATIC". IT MEANS SEA LEVEL CHANGE DUE TO ADDED WATER. OR REMOVED WATER.

YOU CAN FIND AN ABSTRACT OF THE ARTICLE [HERE](#). IF YOU ARE A MEMBER OF AAAS, YOU CAN GO FROM THE ABSTRACT TO THE FULL ARTICLE. MANY LIBRARIES HAVE SCIENCE MAGAZINE ANYWAY.

SEE A DISCUSSION OF IT [HERE](#). THERE IS ANOTHER DISCUSSION [HERE](#) FROM THE NATIONAL SCIENCE FOUNDATION, WHICH FUNDED THE STUDY. THESE ARE PROBABLY EASIER TO READ THAN THE PAPER ITSELF.



**ACCORDING TO THE PAPER IN THE PREVIOUS SLIDE,
GREENLAND IS LOSING 182 BILLION TONS OF ICE PER YEAR (AS
OF 2006). THIS NUMBER IS INCREASING BY 16.2 BILLION TONS
PER YEAR EACH YEAR**

**THAT IS ABOUT 48 CUBIC MILES LOST PER YEAR AND THE
QUANTITY LOST IS INCREASING BY 4.27 CUBIC MILES PER YEAR.
(48 CUBIC MILES IS A CUBE 3.63 MILES ON A SIDE)**

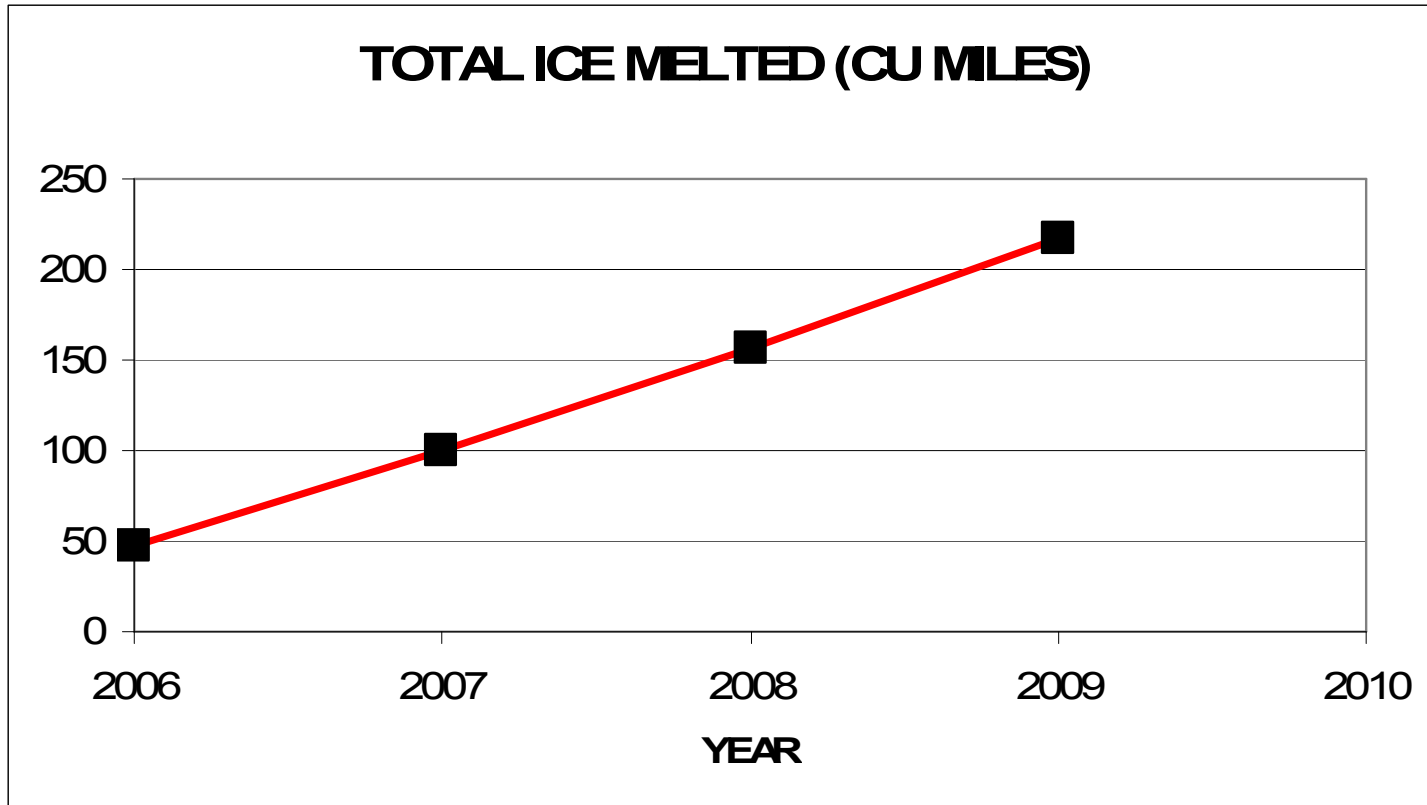
**(BUT GREENLAND HAS AT LEAST A HALF MILLION CUBIC MILES
OF ICE)**

JUST TO MAKE A ROUGH ESTIMATE OF WHAT COULD HAPPEN...

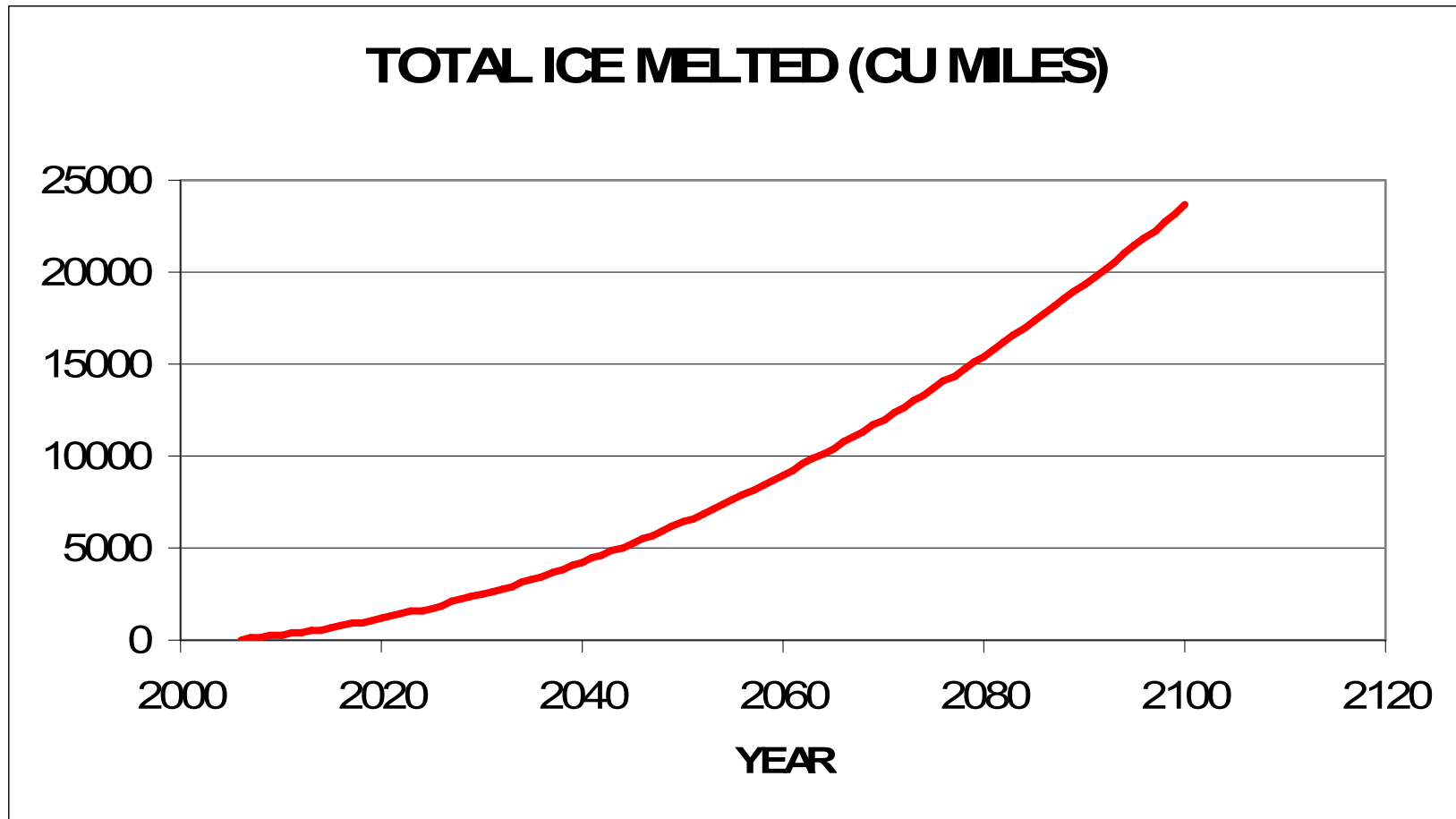
**IMAGINE THAT THE QUANTITY MELTED KEEPS INCREASING BY 4.27
CUBIC MILES EACH YEAR.**

THAT IS,

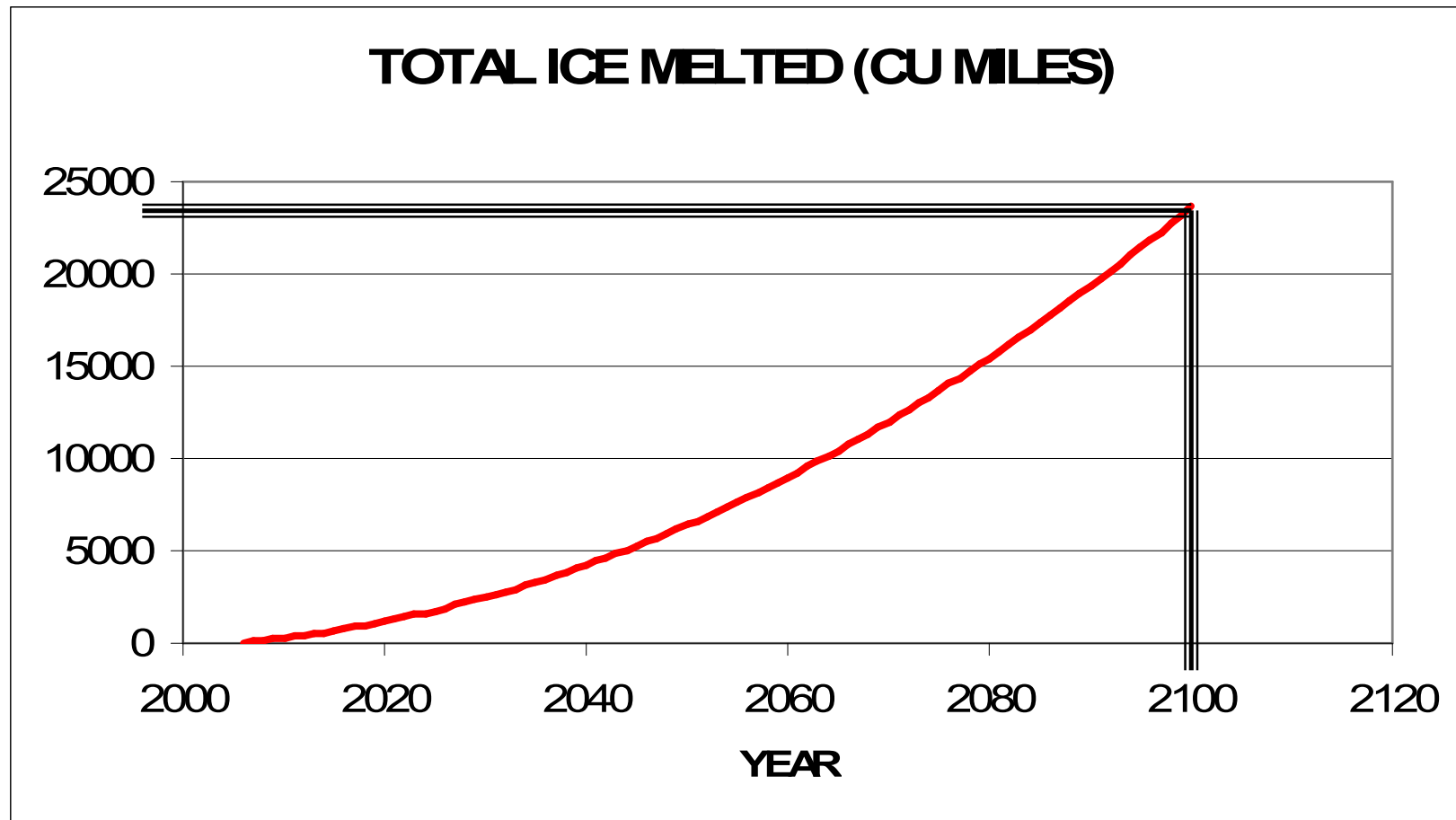
**48.00 IN THE YEAR 2006 FOR A TOTAL OF 48.00 cu miles
52.27 IN THE YEAR 2007 FOR A TOTAL OF 100.27 cu miles
56.54 IN THE YEAR 2008 FOR A TOTAL OF 156.81 cu miles
60.81 IN THE YEAR 2009 FOR A TOTAL OF 217.62 cu miles
AND SO ON...4.27 CUBIC MILES MORE EACH YEAR FOR
HOWEVER MANY YEARS WE WANT TO CALCULATE.**



**WHEN YOU GRAPH THESE TOTALS, YOU GET THIS
(ALTHOUGH IT IS NOT REALLY AS STRAIGHT A LINE AS IT
LOOKS).**

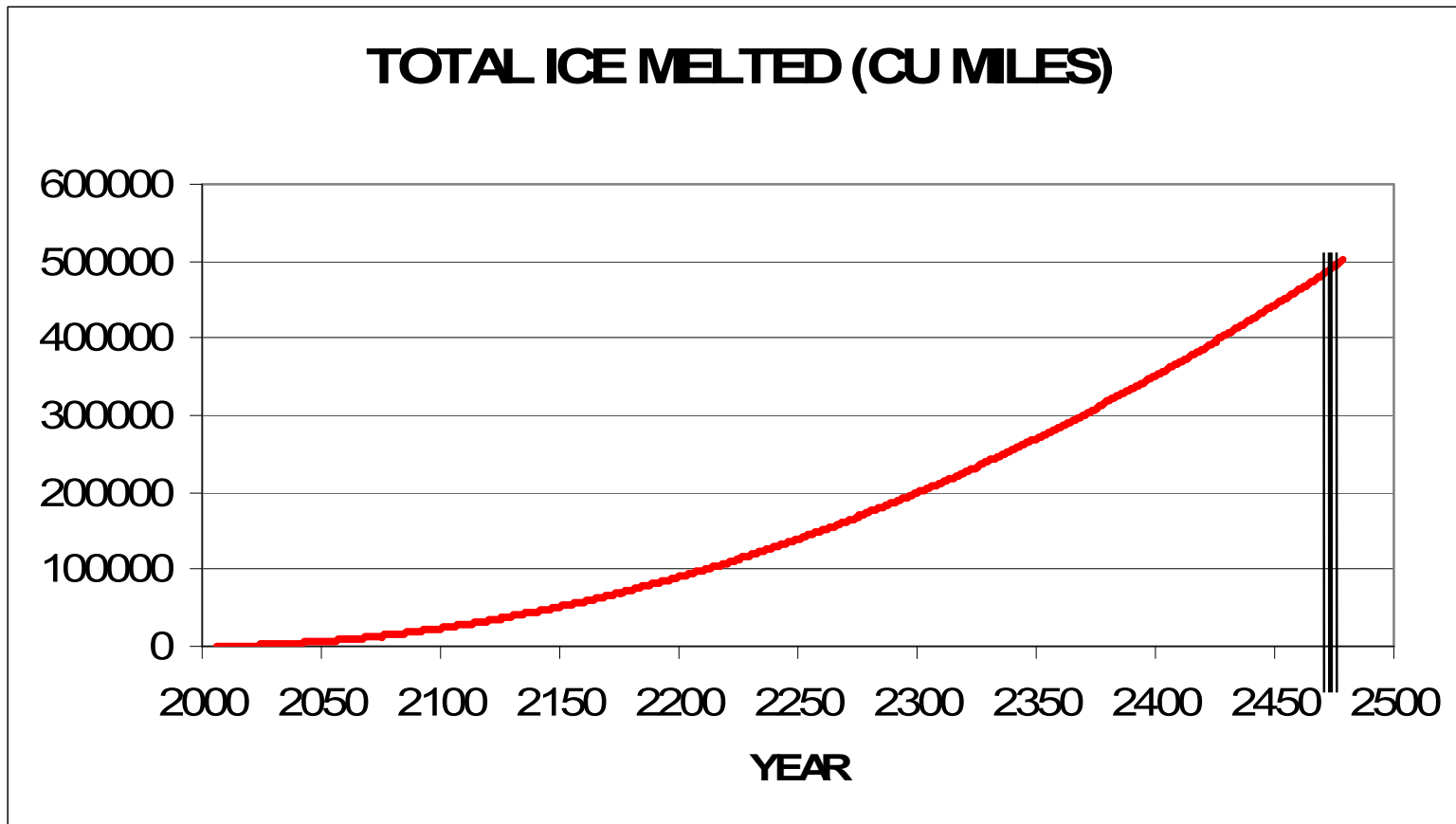


ALL WE HAVE TO DO IS KEEP FIGURING DATA POINTS JUST LIKE WE DID 2 SLIDES AGO. IF WE KEEP DOING IT TO THE YEAR 2100, WE GET THIS.



BY THE YEAR 2100, WE SEEM TO HAVE MELTED ABOUT 23500 CUBIC MILES OF ICE, ACCORDING TO THESE ASSUMPTIONS.

(NOTE: I ACTUALLY WORKED THIS OUT ON A SPREADSHEET, AND IT CAME OUT 23,625 CU MILES.)



JUST FOR FUN, I KEPT THE CALCULATION GOING UNTIL IT MELTED A HALF MILLION CUBIC MILES THAT WOULD BE MOST OF GREENLAND'S ICE. IT HAPPENED IN THE YEAR 2479.

NOTICE THAT THIS IS NOT A FORCAST THAT THE GREENLAND ICE WILL ACTUALLY MELT THIS FAST. IT IS JUST EXAMINING THE MEANING OF THE 2006 TREND.

THE 2100 TOTAL (23625 cu miles) CORRESPONDS TO JUST UNDER A FOOT OF SEA LEVEL RISE.

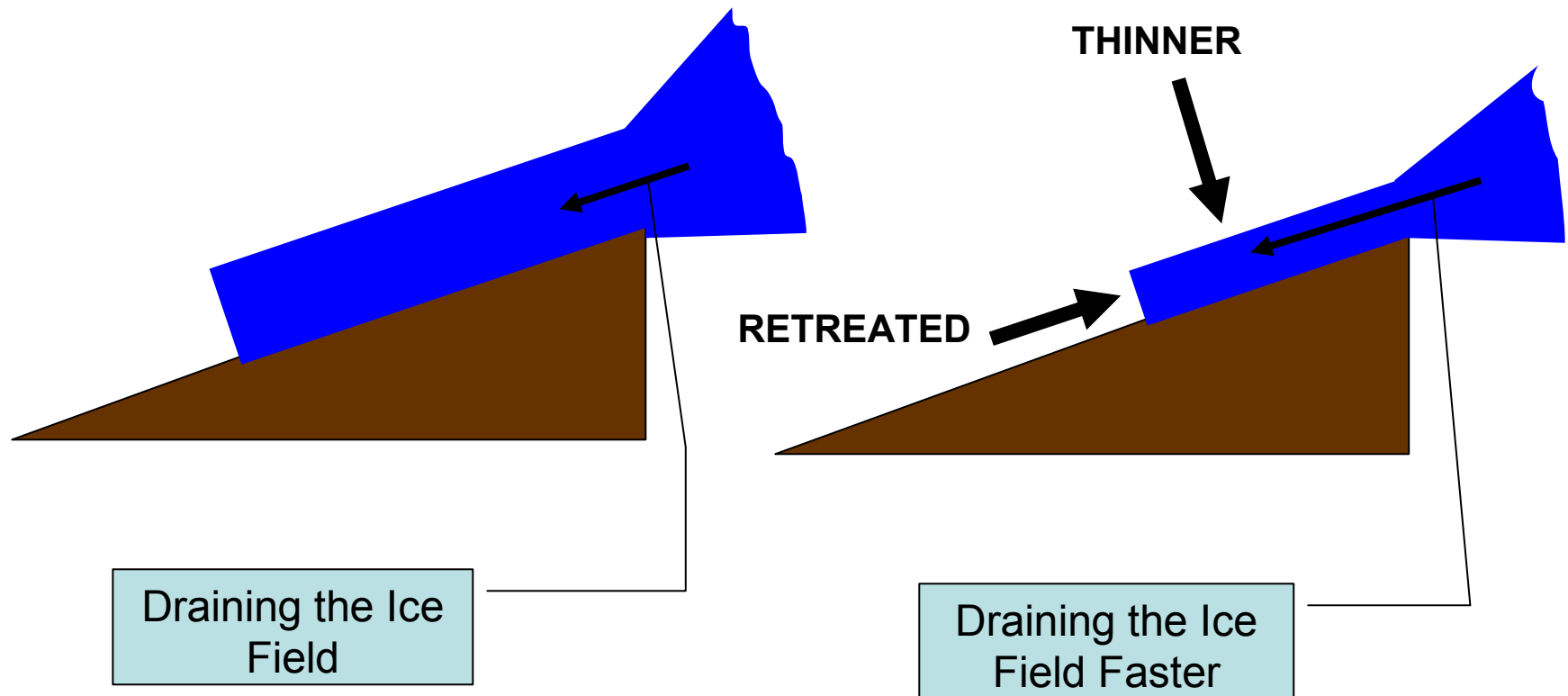
MELTING THE ENTIRE GREENLAND ICE SHEET WOULD RAISE THE SEA LEVEL ABOUT 21 FEET.

THERE IS MORE ON SEA LEVEL RISE IN CHAPTER 11.

HERE IS THE LOCATION OF THE JAKOBSHAVN GLACIER, WHICH DRAINS ICE FROM PART OF THE GREENLAND ICE SHEET. IT IS GREENLAND'S FASTEST GLACIER, AND IT ILLUSTRATES HOW ICE IS LOST FROM GREENLAND BY MEANS OF FLOWING DOWN THESE OUTLET GLACIERS.



IN [THIS ARTICLE](#) FROM OHIO STATE UNIVERSITY, THE JAKOBHAVN GLACIER IS DESCRIBED AS THICKENING BETWEEN 1991 AND 1999 AFTER WHICH IT STARTED TO BECOME THINNER AT A RATE THAT EVENTUALLY REACHED AROUND 39 FEET EACH YEAR. IT IS ALSO RETREATING AND MOVING FASTER.



**HERE IS SOME NASA DATA SHOWING THE RETREAT OF THE
GLACIER IN THE 2001 – 2003 TIME PERIOD.**



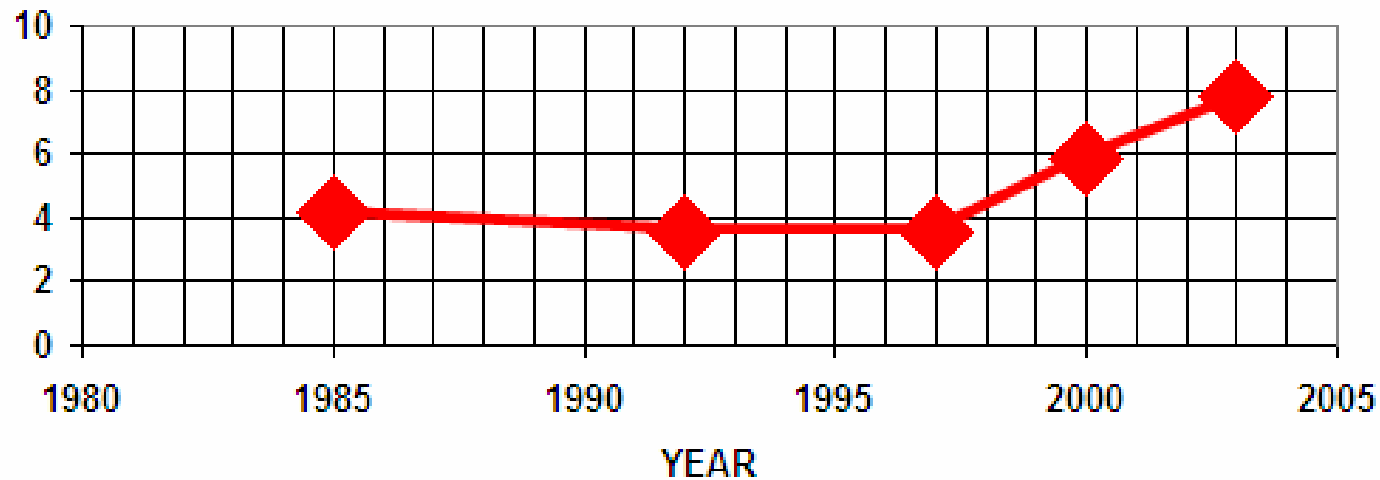
THIS IS FROM AN ARTICLE AT

<http://www.nasa.gov/vision/earth/lookingatearth/jakobshavn.html>

**WHICH SAYS, AMONG OTHER THINGS, THAT THIS GLACIER IS
GREENLAND'S LARGEST OUTLET GLACIER, DRAINING 6.5% OF THE
GREENLAND ICE SHEET. ITS DISCHARGE OF ICE HAS DOUBLED
SINCE 1997.**

THIS [SAME ARTICLE](#) GIVES THE DATA SHOWN BELOW SHOWING THE INCREASING SPEED OF THE JAKOBHAVN GLACIER:

SPEED OF JAKOBHAVN GLACIER IN MILES PER YEAR



THIS GLACIER ALONE IS RESPONSIBLE FOR ABOUT 4% OF THE 20TH CENTURY RATE OF SEA LEVEL RISE ACCORDING TO

<http://svs.gsfc.nasa.gov/vis/a000000/a003100/a003141/>

THAT IS ABOUT 0.06 MILLIMETERS (0.002 INCH) PER YEAR.

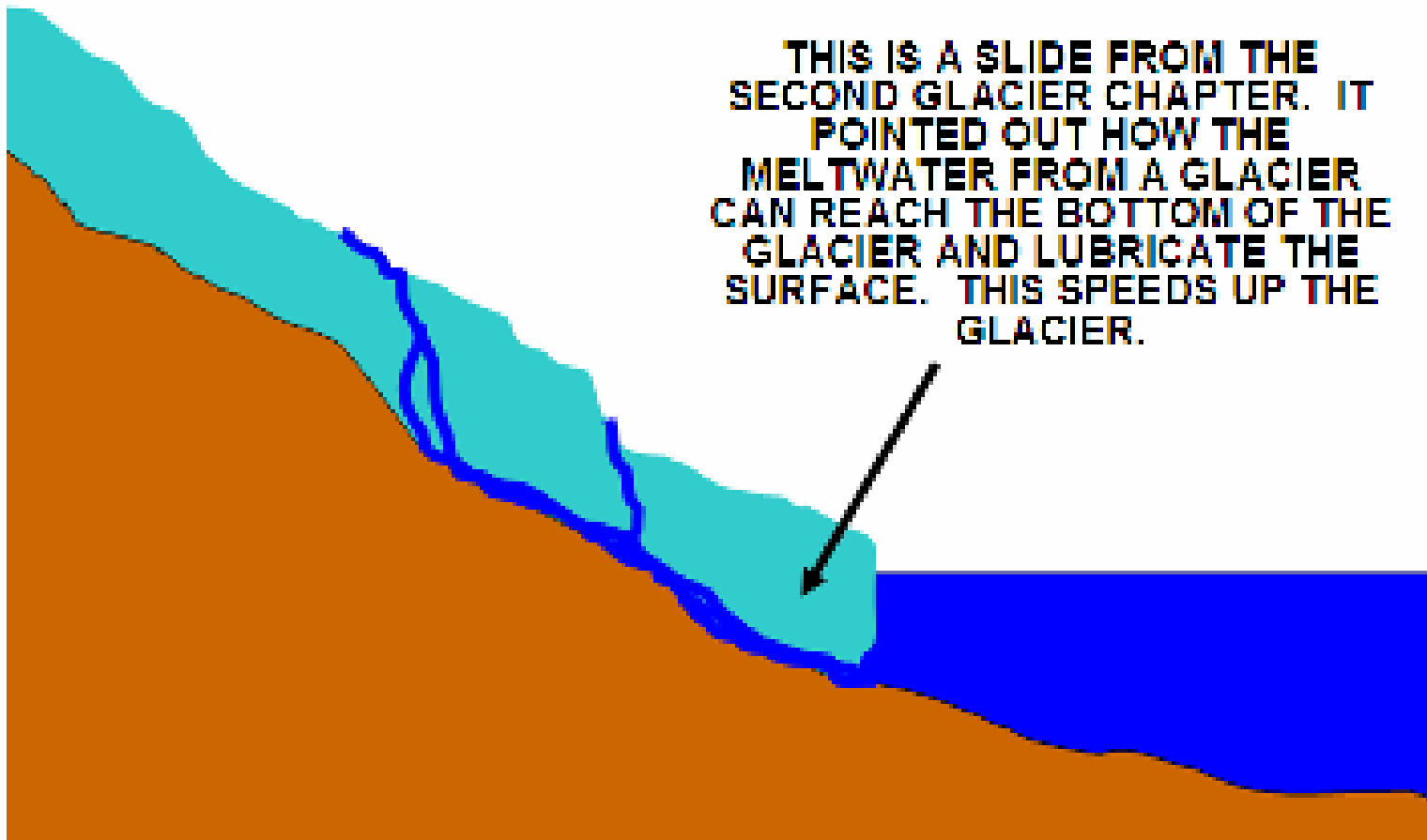
THE POINT OF THIS IS THAT IT DESCRIBES HOW THE LOSS OF ICE IN GREENLAND TAKES PLACE – THROUGH OUTLET GLACIERS.

THIS NPR REPORT DESCRIBES A MORE RECENT (2007) LOOK AT THIS SAME GLACIER BY PEOPLE WHO ARE TRACKING THE MELTWATER ON ITS SURFACE:

<http://www.npr.org/templates/story/story.php?storyId=17587215>

THERE ARE MELTWATER LAKES ALL OVER THE GLACIER UP TO AT LEAST 50 MILES FROM THE COAST. THIS WATER COLLECTS IN LAKES ON THE GLACIER, BUT THOSE LAKES ARE NOT PERMANENT. THE WATER EATS INTO THE GLACIER AND EVENTUALLY TUMBLES ALL THE WAY TO THE BOTTOM.

**THIS IS A SLIDE FROM THE
SECOND GLACIER CHAPTER. IT
POINTED OUT HOW THE
MELTWATER FROM A GLACIER
CAN REACH THE BOTTOM OF THE
GLACIER AND LUBRICATE THE
SURFACE. THIS SPEEDS UP THE
GLACIER.**





THIS PICTURE IS ALSO FROM THE SECOND GLACIER CHAPTER (CHAPTER 7). IT IS NOT FROM GREENLAND, BUT IT DOES SHOW MELTWATER EATING INTO A GLACIER. I TOOK THE PICTURE ON MEADE GLACIER IN ALASKA.

THIS IS A FEEDBACK MECHANISM THAT IS THOUGHT TO BE SPEEDING UP THE LOSS OF GREENLAND ICE.

**THIS NASA NEWS RELEASE DISCUSSED THE SPEEDUP OF
GLACIERS DUE TO SURFACE MELTWATER PENETRATING TO
THE BOTTOM OF THE GLACIER:**

<http://www.gsfc.nasa.gov/topstory/20020606greenland.html>

**AMONG OTHER THINGS, IT DISCUSSES A STUDY WHICH
SUPPORTS THIS IDEA BY SHOWING THAT THE GLACIER
SPEED IS GREATEST DURING PERIODS WITH THE MOST
MELTING.**

IT ALSO HAS SOME COOL PICTURES.

So, although the warming seems to be mostly confined to the edges of Greenland, that is enough for it to lose increasing amounts of ice.

Much of the ice loss is through glaciers that drain the ice sheet.

The tendency of these glaciers to speed up, or surge, when meltwater tunnels downward and reaches the base likely provides a feedback effect that is accelerating the ice loss.

Now it is time to head for the earth's other pole and check out conditions there. That is in the next chapter.

REFERENCES: Web addresses (paste to your browser, if necessary)

SLIDE 2

<https://www.cia.gov/library/publications/the-world-factbook/geos/gl.html>

Greenland in the CIA World Factbook

<http://edmall.gsfc.nasa.gov/99invest.Site/science-briefs/ice/ed-ice.html>

NASA Description of Greenland

<http://www.benfieldhrc.org/activities/issues5/pages/greenland.htm>

Greenland description from risk management agency

SLIDE 3

<http://www.worldtravelguide.net/country/103/climate/North-America/Greenland.html>

Greenland climate description

SLIDE 9

<http://www.sciencemag.org/cgi/content/abstract/317/5841/1064?rss=1>

Research article abstract on melting ice

<http://www.climateshifts.org/?p=86>

A discussion of the above research article

http://www.nsf.gov/news/news_summ.jsp?cntn_id=109759&org=ARC

Another discussion of the same article

REFERENCES: Web addresses (paste to your browser, if necessary)

SLIDE 18

<http://researchnews.osu.edu/archive/greenice.htm>

Ohio State University research article on Greenland glaciers

SLIDE 20

<http://www.nasa.gov/vision/earth/lookingatearth/jakobshavn.html>

NASA article on the Jakobshavn Glacier (same one referenced in Slide 19)

THERE ARE A NUMBER OF OTHER LINKS TO REFERENCES IN SEVERAL SLIDES IN THIS CHAPTER WHICH ARE ALREADY IN THE FORM OF WEB ADDRESSES. IF YOU HAVE TROUBLE REACHING THEM BY CLICKING, THEN PASTE THEM INTO YOUR BROWSER.

**CONTINUE ON AND RETURN TO
THE GLOBAL WARMING MENU**

**THEN LOOK AT
CHAPTER 10**

**“Poles Apart – The
Antarctic”**