POLAR WEEKEND

SUBGLACIAL LAKES

TOPIC: AN Unknown Subglacial World

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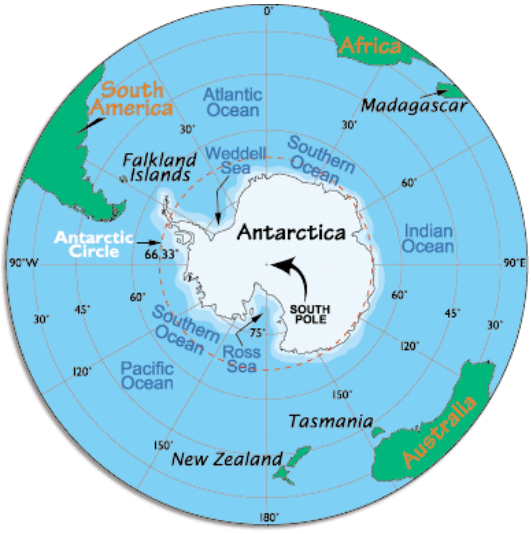


WHERE ON THE MAP ARE WE? This image shows the full continent of Antarctica and how it relates to the world around it. Antarctica 'caps' the southern reaches of the Earth. Unlike the Arctic, Antarctica is an ice covered land based continent surrounded by water. If you follow the 'tail' of Antarctica on the left side of the image you will reach the tip of South America. Other sections of Antarctica line up with Africa and Australia. Scientists have found evidence of subglacial lakes throughout much of Antarctica; in other areas of Antarctica there is not enough data collected to tell if they exist or not.

(image from worldatlas.com)

GENERAL BACKGROUND INFORMATION ON THE SUBJECT:

What are Subglacial Lakes? Subglacial Lakes are lakes that exist underneath the ice sheet! Imagine that ice floats on these lakes, even when the ice is 2 miles thick! How does water form and stay liquid under ice? Geothermal heat, the heat coming out of the center of the earth, occurs throughout the world. In fact this heat actually keeps deep mines, down towards the core of the Earth, hot! In Antarctica it can cause warming and melting at the bottom of the ice sheet. Additionally, pressure from the several miles of ice thickness can warm the base causing further melting. There are over 160 subglacial lakes currently located in Antarctica with Lake Vostok being the largest at the approximate size of Lake Ontario in Canada. The image here is an inventory of the subglacial lakes that have been located using radar data.

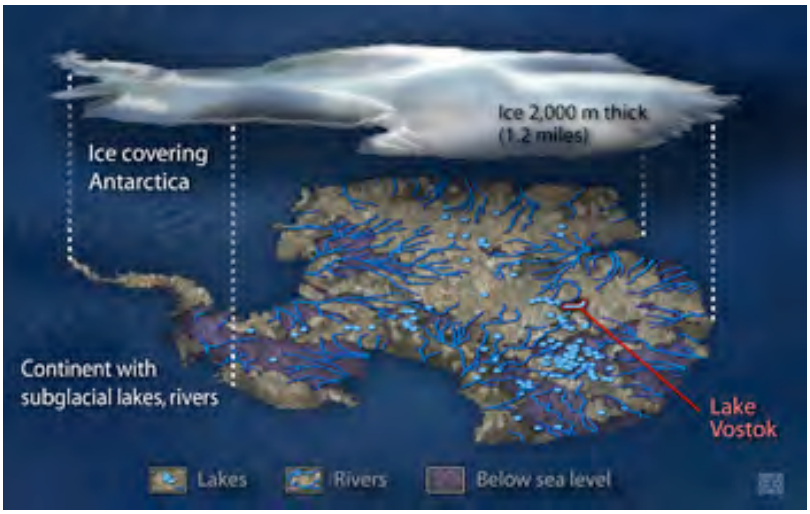


Image of the Antarctic continent showing the ice lifted off and the Lakes underneath. (by Zina Deretsky)

How do we locate the lakes? If you were to walk on the surface of the ice sheets the lakes would not show up. Much of the Antarctic ice sheet is flat, so you do not see evidence of the lakes when you are over them. How do we know there are lakes under the ice? Scientists have used radar data to image through the ice in Antarctica. The radar waves can provide information on the thickness of the ice and even the internal layers of the ice. When the radar hits water it can't go through. The return image comes back as flat and bright since it bounces right back.

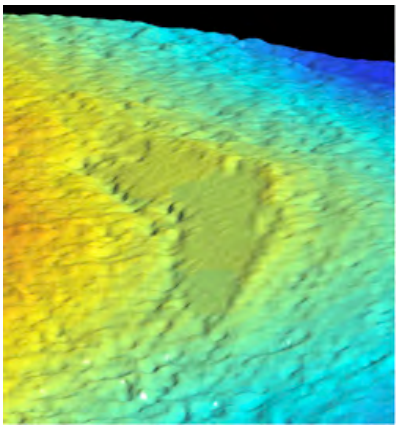


Image of Lake Vostok by M. Studinger.

How much water is in these lakes? Scientists believe that if you took the combined volume of these lakes it would equal nearly one third of all the rest of the surface water on the Earth. While it was once believed these lakes were isolated from the surface and each other, like under ice museums, we now know this is NOT true.

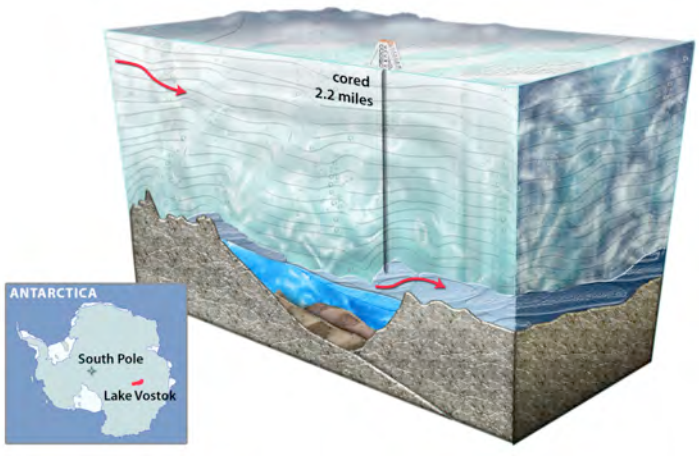
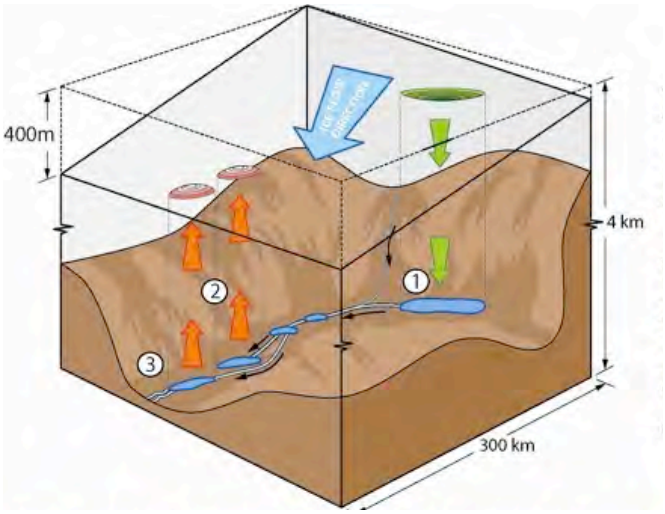


Image by N. Rager-Fuller, NSF, of water movement through Lake Vostok

Although the lakes are unique environments that have been isolated from the Earth's surface for millions of years, recent findings suggest that water moves in and out of many of these lakes in different ways. Lake Vostok seems to move water in out of the lake slowly and steadily through the surface water in the lake freezing onto the overlying ice sheet as it moves out of the lake. This is referred to as "accretion". Through this constant accretion of ice as it moves out of the like and melting of ice as it moves into the lake you get a slow movement of water through the system and not the rapid drainage that scientists have seen in some lakes. Other lakes, are connected more like a stack of dominoes with a more dramatic emptying and filling from one lake another at a lower elevation, and so on. This connection of lakes under the ice can play an important role in the changing ice sheets. In recent years scientists found a cluster of lakes like this in the Whillans and Mercer ice stream on the Ross Ice Shelf.



The image shown here shows an occurrence on the Ross Ice Shelf where water moved through in a series of 3 lakes. The surface of Lake 1lowered 4 meters as water was transferred to lakes 2 and 3 (both of which raised as a result). ~1.8 km^3 of water was displaced in 16 months as it moved from one lake to another. Unlike Lake Vostok, when water moves in and out of these lakes you can see the change on the ice sheet surface.

Image from Wingham et al, Nature 2006

What triggers this movement in the lakes? Subglacial water is under a tremendous amount of force from the ice sheet over top of it. The ice streams over the lake it can shift causing pressure to increase in an area thus forcing water to another area. The water in the new location adds to the pressure there and so it continues to drain from one lake to another just like the dominoes we noted above. As the water moves out of one lake the ice surface drops, and into another where the surface rises.

How does water underneath affect the ice sheet? Ice sheets flow! They are in constant motion as gravity tugs on them. Movement within the ice sheet can be very slow creeping along at a few meters a year. Subglacial water can actually lubricate the bottom of the ice sheet causing it to speed up to 20 or 30 meters a year, or more. As the ice reaches the wet surface is starts to slide, as if it stepped on a banana peel!

TERMS YOU SHOULD KNOW (VOCABULARY):
Accrete – The freezing on of water to ice as the ice moves over the lake.
Ice sheet – thick piece of ice often over 2 miles thick that can cover an entire continent
Glacier - slow moving mass of ice often found high in the mountains and in polar regions
Subglacial – beneath a glacier or ice sheet/ **Subglacial Lake** – Lake beneath an ice sheet
Subglacial Environments – The environments beneath an ice sheet can include lakes, rivers, streams, swamps
Vostok – Russian word for East/ **Vostok Station** – Russian Station in East Antarctica
Lake Vostok – Biggest subglacial lake found under 2 miles of ice under Vostok station
Ice Streams – Rivers made of ice that act like a conveyor belt moving ice in an ice sheet towards the ocean where it becomes icebergs

WHY ARE WE STUDYING THIS IN THE POLAR REGIONS?
There is a lot of water under the Antarctica ice sheets - it collects in lakes, flows between different lakes, in rivers and even drains out in huge flood events. These are unique environments that we did not know existed 10 years ago. What have learned?
•Ice sheets Insulate – the top of an ice sheet is cold (-50C) but the bottom is warm. The ice sheet traps the geothermal heat just like a blanket traps your body heat at night
•Ice Melts from Heat – The bottom of an ice sheet can get so warm that it melts!!!
•Ice Melts from Friction – If you add friction to the bottom of an ice sheet it will also melt!!
•Ice Sheets are Old – The ice at the bottom of the Antarctic ice sheet is almost 1 million yrs. old!!

HOW DOES THIS AFFECT US HERE IN THE UNITED STATES?
Water, in subglacial lakes or streams, can make the bottom of the ice sheet slippery like a banana on a sidewalk. Water draining out of a lake may make the ice sheet flow faster, carrying it towards the ocean where pieces can break off. This can have a wide reaching effect including sea level rise, reduced marine environments, climate change from reduced reflectivity.

Activity for you to try:
Supplies:
2 plastic shoebox type containers
2 nozzles
1 section of rubber tubing
2 pieces of Styrofoam cut to fit into the shoeboxes
Gravel
Water & ice (if desired)

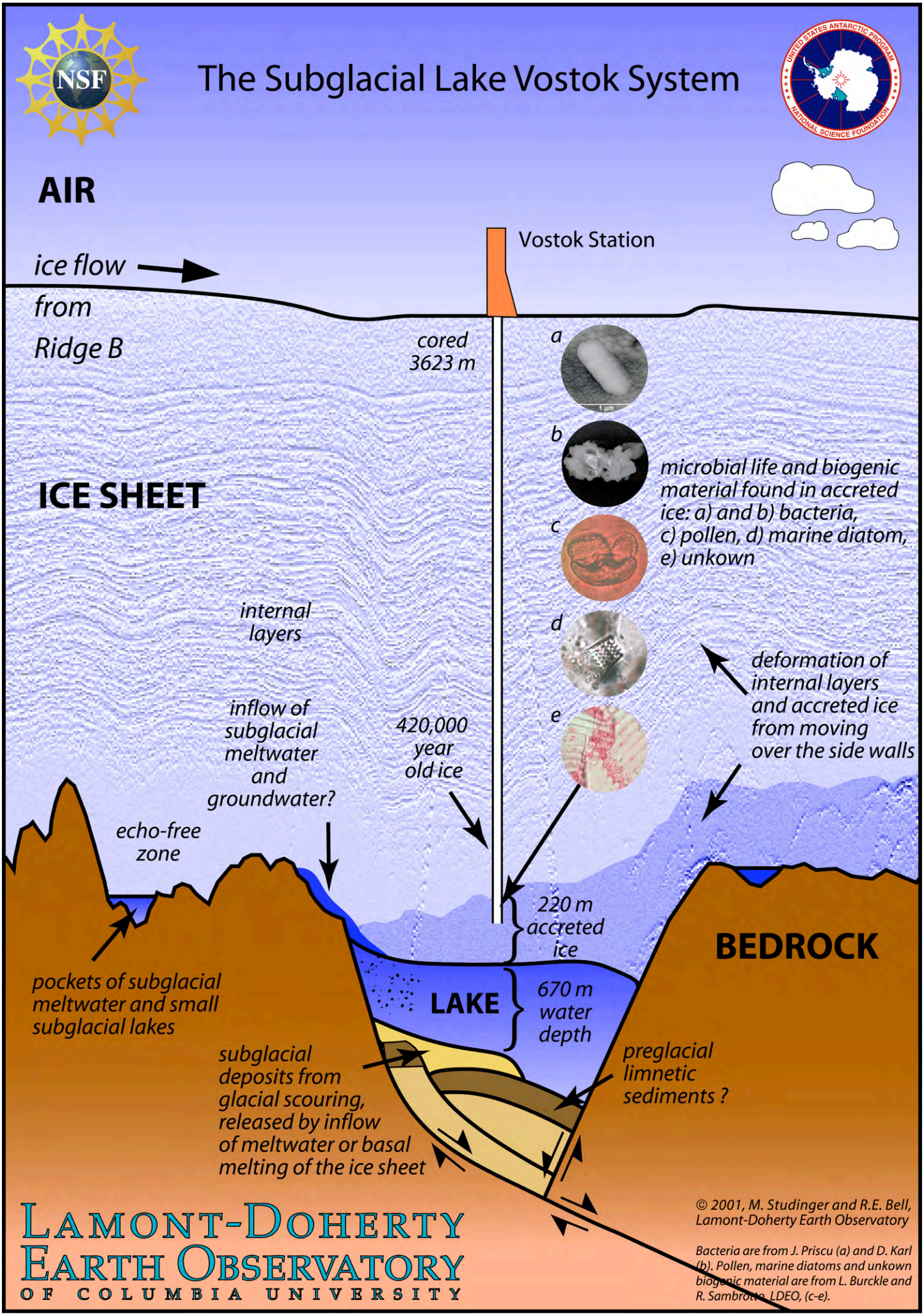
Collect two plastic shoebox type containers. These will be your 'subglacial lakes'. Put a hole fitted with a nozzle end into the end of each container, and connect with a piece of rubber tubing. This will represent the under ice connection between the two lakes. Place a gravel bedding in both containers to represent the bed of the lake. Then add water to the bottom of the both lakes. Be sure not to fill them too full so that there is room for the water to move back and forth from one to the other. Place one of the containers at a higher elevation than the other (a book or two will do the trick) so that there will be flow from one to the other. The flow from the elevated lake to the lower lake represents the movement of ice through the subglacial environment.

• Time the movement of water from one lake to another.
• Now push on the 'ice sheet' on the higher elevation lake. What happens to the time it takes to move from one lake to another?
• What does 'pushing' on the ice sheet represent in the real subglacial lake system?
• This type of set up demonstrates lakes that have changes in surface elevation as they drain from one. Looking back at the section above does this type o set up best describe water movement in: a) Lake Vostok OR b) the lakes on the Whillans & Mercer Ice Stream? Explain your answer?

For a fun set of subglacial activities visit:
http://www.ldeo.columbia.edu/res/pi/gambit/AdrienneBethAdventureLakesB.htm

TO LEARN MORE ABOUT THIS TOPIC:
http://www.ldeo.columbia.edu/res/pi/gambit/SubglacialLakes.htm
http://www.ldeo.columbia.edu/~mstuding/vostok.html

The Subglacial Lake Vostok System



LAMONT-DOHERTY EARTH OBSERVATORY
OF COLUMBIA UNIVERSITY

Bacteria are from J. Priscu (a) and D. Karl (b). Pollen, marine diatoms and unkown biogenic material are from L. Burckle and R. Sambrotto, LDEO, (c-e).

Antarctica's Subglacial Lakes

An (almost) Unknown World

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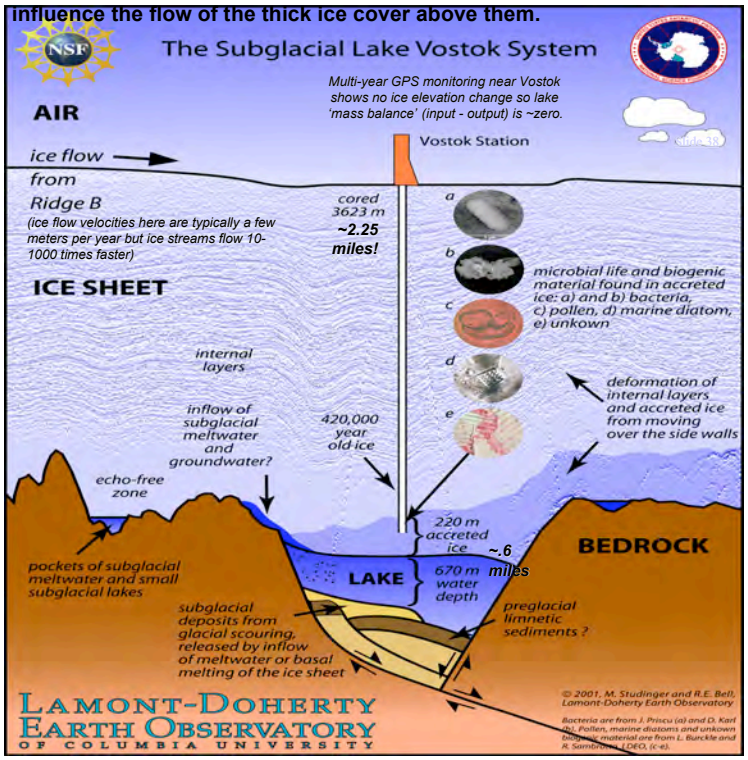
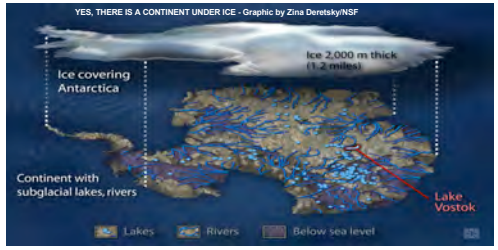
What is a 'subglacial lake'?

A subglacial lake is a short- or long-term reservoir of water beneath a glacier, ice cap, or ice sheet. The world's largest and deepest is Lake Vostok in East Antarctica at ~15,000 sq kilometers (~5,800 sq miles). Many smaller lakes are found throughout East and West Antarctica and influence the flow of the thick ice cover above them.



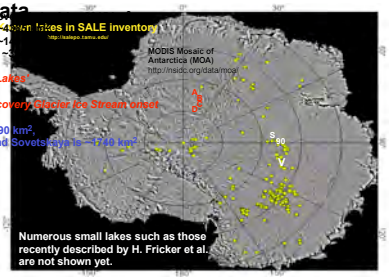
Why Do We Need To Know This?

In order to understand and predict the mass balance trends of the Earth's ice, the major unknown in sea level rise, all the factors that influence ice masses need to be quantified by climate models. Subglacial lakes provide lubricating water that enables accelerated ice stream flow and form part of a flow network that could rapidly discharge fresh water into the global ocean. These (nearly) hidden water bodies may also contain unique life forms that have been relatively isolated from broader environmental influences.

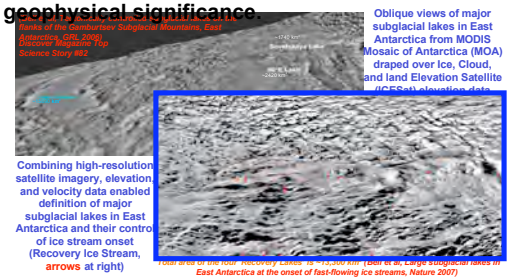


Recent discoveries across Antarctica

Although Lake Vostok (V) has been known about for decades and has almost been drilled into, its smaller neighboring lakes, Sovetskaya (S) and 90 East, were only recently mapped by 3D NASA satellite data.



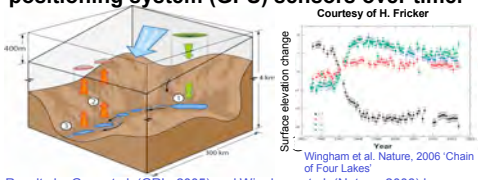
The four Recovery Lakes were defined even more recently and appear to control the onset of faster ice flow within the Recovery Ice Stream system which penetrates deep into the Antarctica. Initial ground data was acquired in the mid-1960s but it required satellite data to define their size and geophysical significance.



How do we know they are there?

One way is through direct observations as their floating ice cover is unusually flat (even for very low slope ice sheet surfaces) and another is through geophysical tools like gravity and radar sensors. Here Dr. Ted Scambos uses a gravimeter to detect the presence of water in one of the recently discovered 'Recovery Lakes' deep beneath the

Another way is by precisely measuring elevation changes with ground-based global positioning system (GPS) sensors over time.



Results by Gray et al. (GRL, 2005) and Wingham et al. (Nature, 2006) have shown that subglacial water can move rapidly in large quantities in "subglacial floods" and cause detectable ice elevation changes.

And, satellite and aircraft altimeters offer yet another way to monitor ice surface elevation changes associated with water movements at the base of the ice sheet. As water flows in or out, the topography over the lake can remain