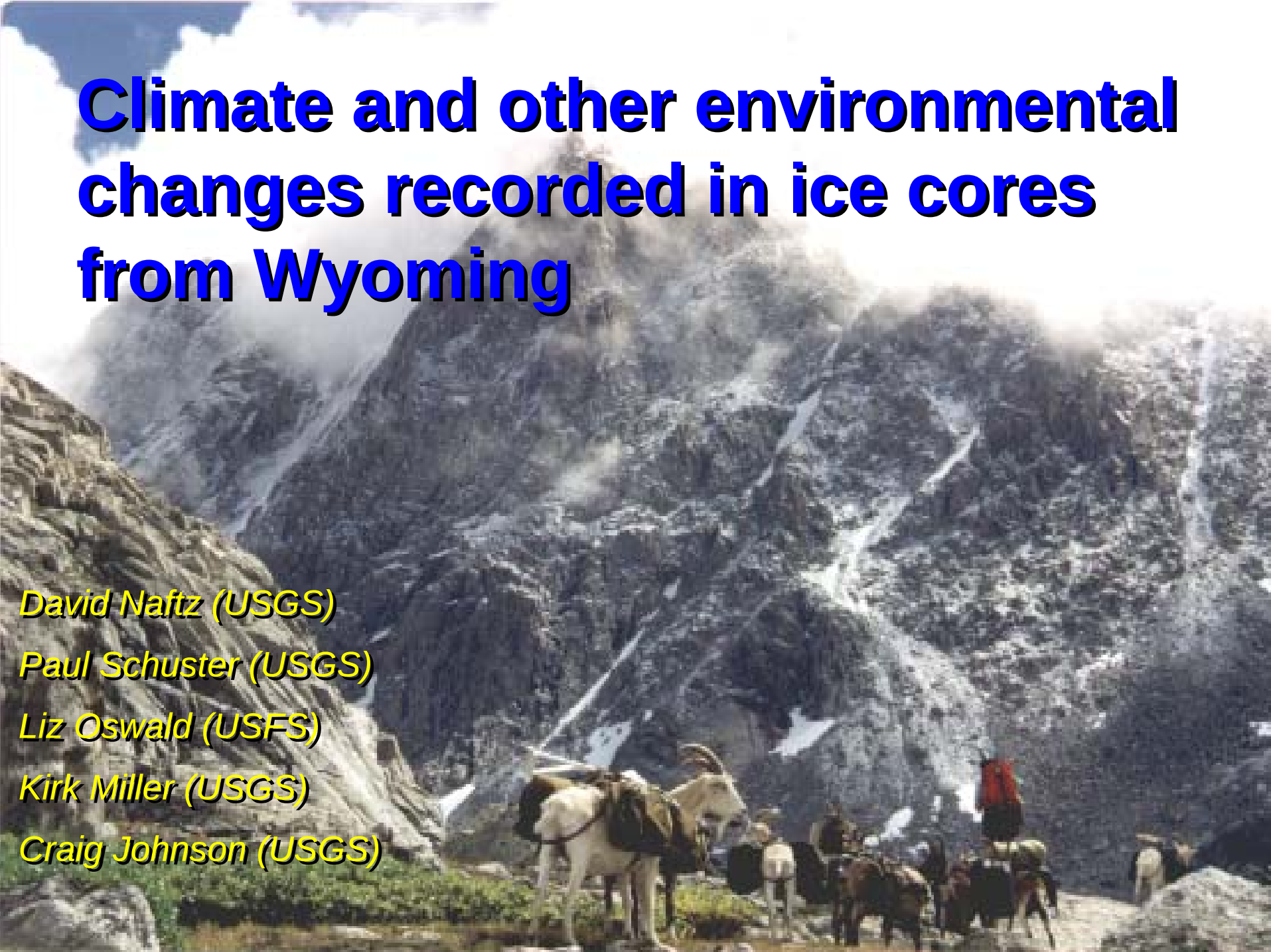
Climate and other environmental changes recorded in ice cores from Wyoming



David Naftz (USGS)

Paul Schuster (USGS)

Liz Oswald (USFS)

Kirk Miller (USGS)

Craig Johnson (USGS)

Wind River Glaciers 1981

Dave and Marlene's honeymoon

Old USGS saying:

"Find a place where you want to work and then figure out how this place can be used to answer a question."

QUESTIONS

Has the average air temperature changed in alpine areas in the Wind River Range?

Are glaciers in the Wind River Range responding to accelerated warming?

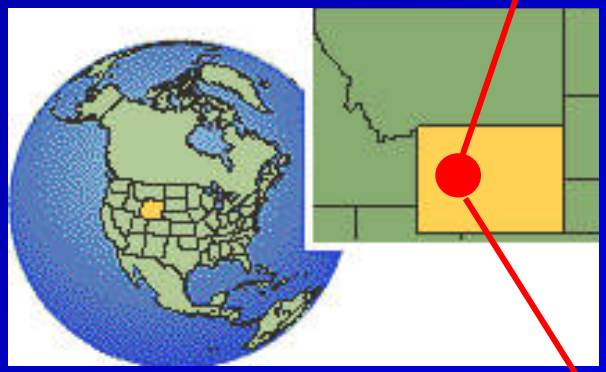
Are offsite NO_X and SO_2 emission amounts and sources recorded in the ice-core record?

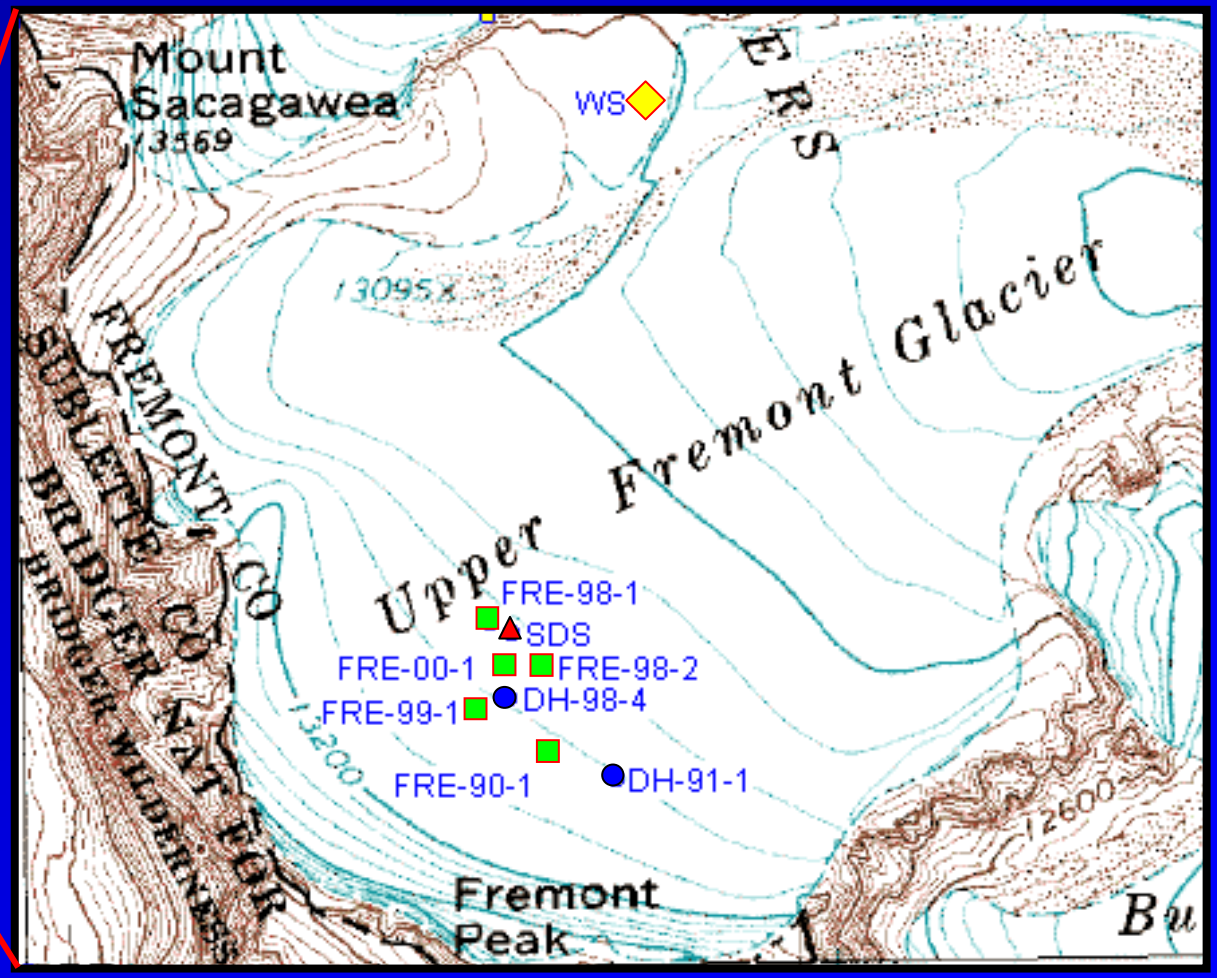
UPPER FREMONT GLACIER

Goat packing to Upper Fremont Glacier

- **Fitzpatrick Wilderness Area**
- **Drilling sites exceeding 4,000 m ASL**
- **Ice thickness exceeding 160 m**
- **Largest concentration of glaciers in Rockies (lower 48)**
- **Flat surface topography (ice sheet)**

UPPER FREMONT GLACIER, WY





0 0.2 KM

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Has the average air temperature changed in alpine areas in the Wind River Range?

Earthweek: A Diary of the Planet

By Steve Newman

Island Warnings

Volcanologists on the Caribbean island of Montserrat advised residents to protect their roofs from falling ash following an explosion from within the Soufriere Hills Volcano. The scientists attributed the volcanic activity to a partial collapse of the mountain that caused hot rocks and gas to be released from its eastern flank. Peter Dunkley, director of the volcanology observatory, also warned of a possible increase in volcanic activity during the coming months.

• Residents of an Indonesian North Sulawesi island were banned from returning to their communities as Ruang Volcano continued to spew black smoke, ash and lava nearly 10,000 feet into the sky.

Hotter Summer Nights

Cities in the United States have an average of 10 more hot nights a year than they did 40 years ago, according to climate researchers at Cornell University. Arthur T. DeGaetano, associate professor of earth and atmospheric sciences, reviewed temperature trends over the past century from climate-reporting stations across the United States. He said, "I expected maybe a 25 percent increase for the urban areas compared to the rural ones. I didn't expect a 300 percent increase across the U.S." Although temperatures in rural areas seem to have remained relatively constant during that period, urban and suburban areas, particularly in major East Coast cities, have more hot summer nights than ever.

Tropical Cyclones

At least four people were killed and one other person was reported missing as super typhoon Higos made landfall on Japan's main island of Honshu.

• Category 4 hurricane Lili inflicted further damage over storm-weary western Cuba and Jamaica before striking Louisiana late in the week.

• Tropical storm Kyle drifted over the Atlantic, northwest of Bermuda.

Earthquakes

At least five people in the southwestern Iranian province of Khuzestan were injured when a magnitude 5.5 temblor seriously damaged nine communities.

• A magnitude 5.4 earthquake that struck western France's Brittany coast panicked residents who fled into the streets.

• Earth movements were also felt in Slovenian, Sicily, the Greek island of Rhodes, northern Afghanistan and Taiwan.

Ice Shows Warming

U.S. Geological Survey scientists announced that data obtained from the analysis of ice core samples collected at a remote glacier in northwestern Wyoming show that air temperatures in that area have undergone a dramatic increases since the early 1700s. This is the first time that ice core samples from within the continental U.S. have been studied. Stable isotope ratios of oxygen preserved in ice cores collected from the site were used to reconstruct long-term variations in air temperature. They revealed that the air temperature at the high-elevation site has increased by more than 6 degrees Fahrenheit during the past 40 years alone. The recent rates of warming reconstructed from the ice-core data are more than four times higher than the global average during the past 100 years.

West Nile Monitoring

Brazil has organized an epidemiological surveillance operation to monitor birds migrating into the country from the United States for infection of the West Nile virus. The virus, which has killed more than 100 people in the U.S. during the past three years, can cause encephalitis and meningitis in its more severe form. More than 30 bird species migrate from the U.S. to Brazil each year, and remain from October through April. The monitoring program will dispatch teams to remote forest and waterway regions where the birds gather upon arriving in Brazil.

Ice Meteors

The increase in the number of reported ice meteors, known as megacryometeors, is a symptom of global warming, according to a Spanish planetary scientist. Jesus Martinez-Frias, who has studied the phenomenon of ice chunks falling from the sky, said that the pieces of ice formed from crystallized vapor trails of aircraft. Global warming's effect on different levels of the atmosphere has caused some of the ice clouds to remain suspended longer. They then gather mass as they fall through the atmosphere, according to the scientist. He emphasized that the ice meteors were neither hoaxes nor blocks of ice falling from the bathrooms of passing airplanes, as some have suggested. The huge pieces of ice, which typically weigh more than 22 pounds, fall from clear skies and have shattered windshields and ripped holes through the roofs of homes in Spain.

Distributed by: The Los Angeles Times Syndicate
E-mail: mail@earthweek.com
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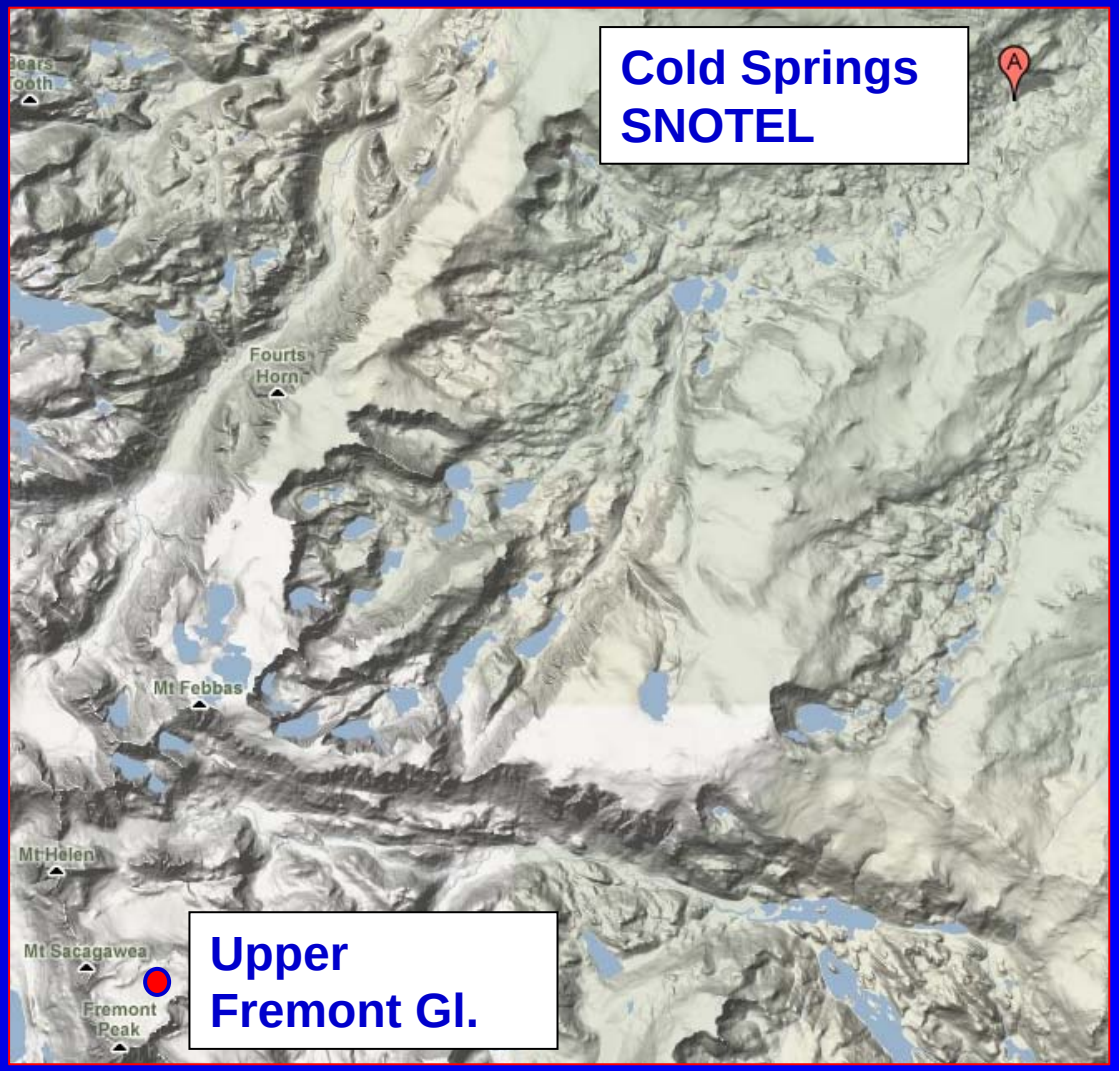
SNOTEL TRANSFER FUNCTION

- SNOTEL elev. = 2,940 m ASL
- UFG elev. = 4,000 m ASL
- 22 km apart



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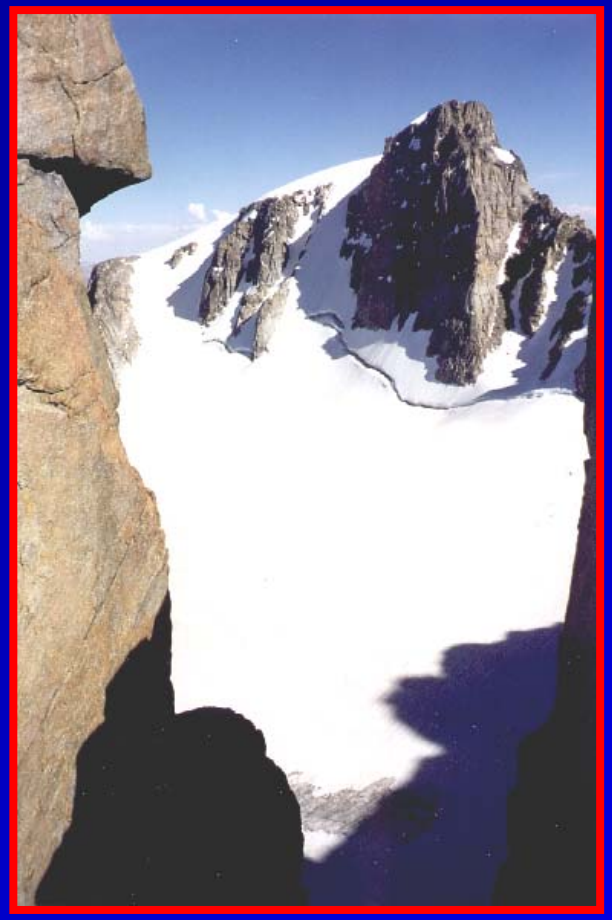
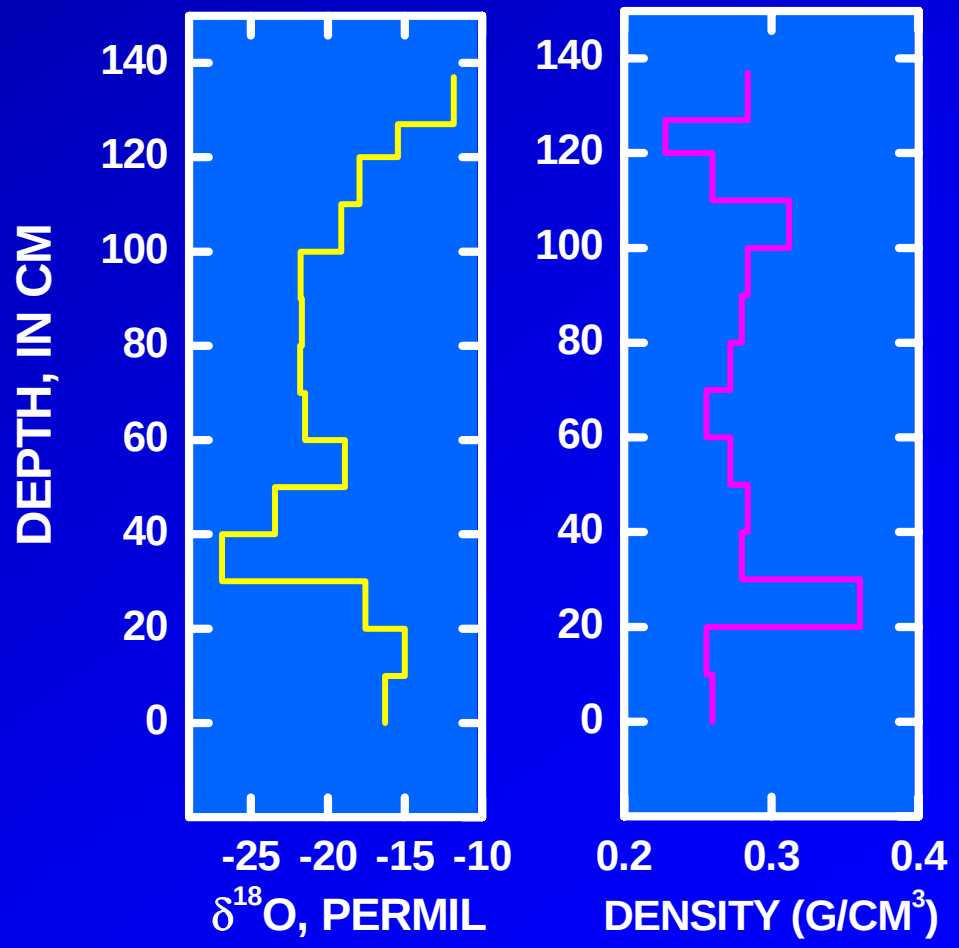
SNOTEL/UFG DATA ASSUMPTIONS



- Wind removal and melting was minimal after deposition
- Storms impact both sites with same relative intensity
- All precipitation is in the form of snow
- Isotopic values are not modified after deposition

SNOW SAMPLING



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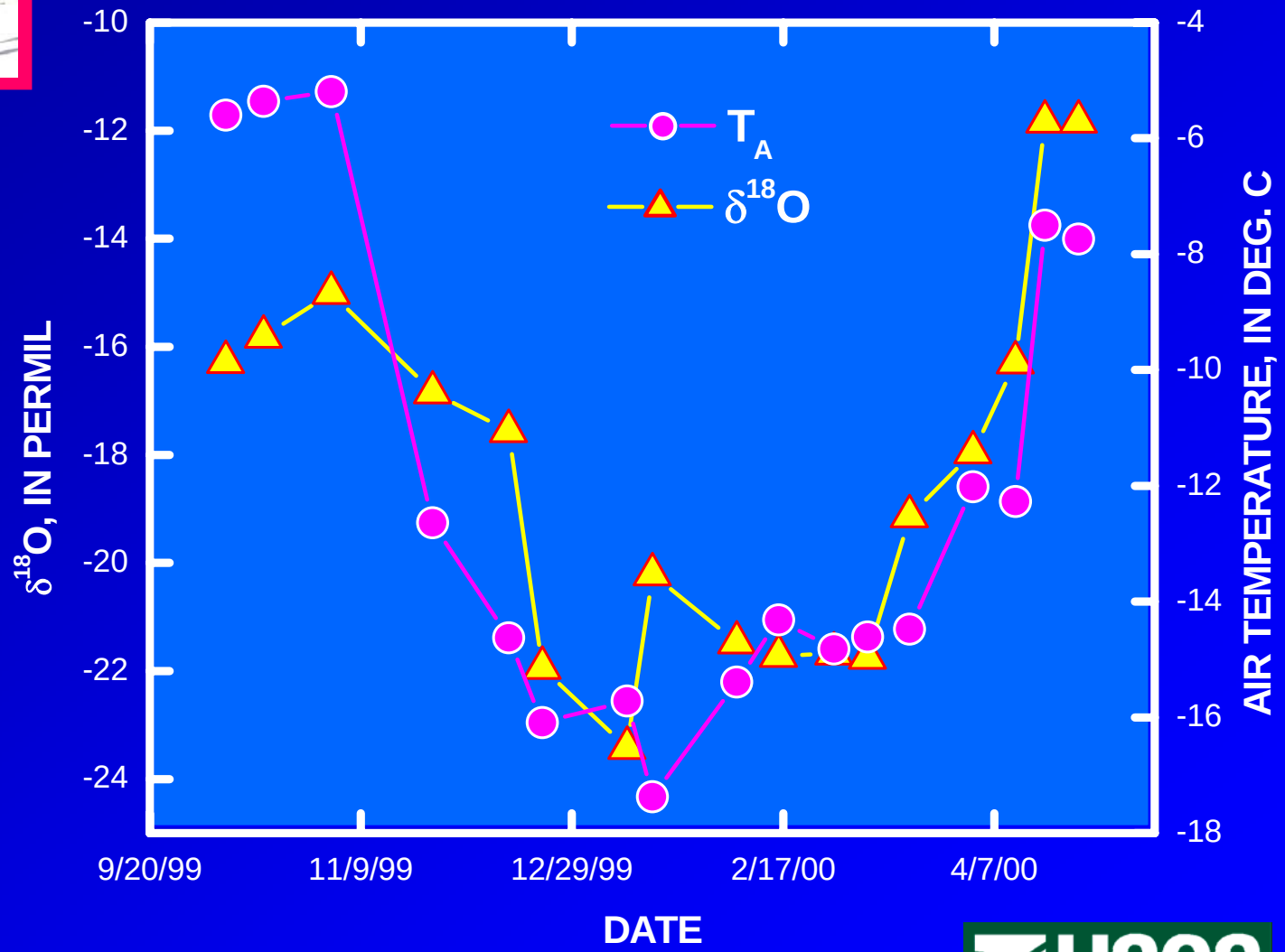
TRANSFER FUNCTION 00



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DEPTH SENSOR INSTALLED

- Records hourly snow depth
- Captures site-specific storms
- Insight into post depositional processes

DEPTH-SENSOR DATA

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Looking at snow-depth data differently

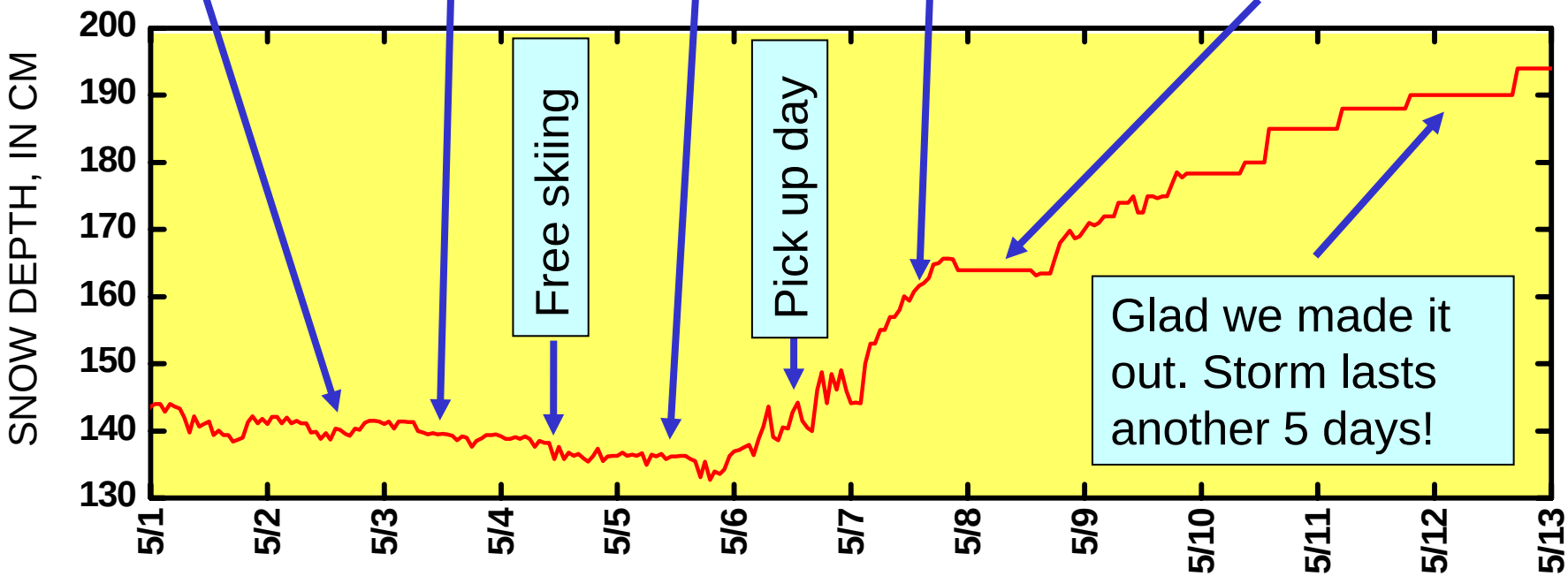
Ski to base camp

Sample all day

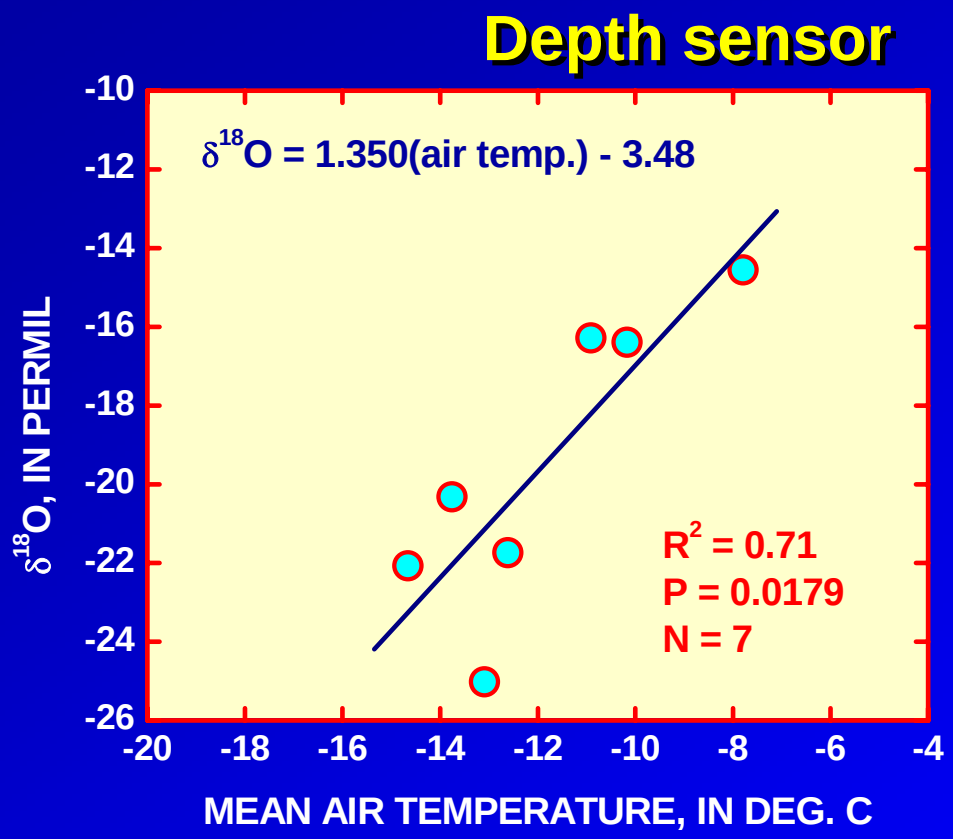
Back to drop zone

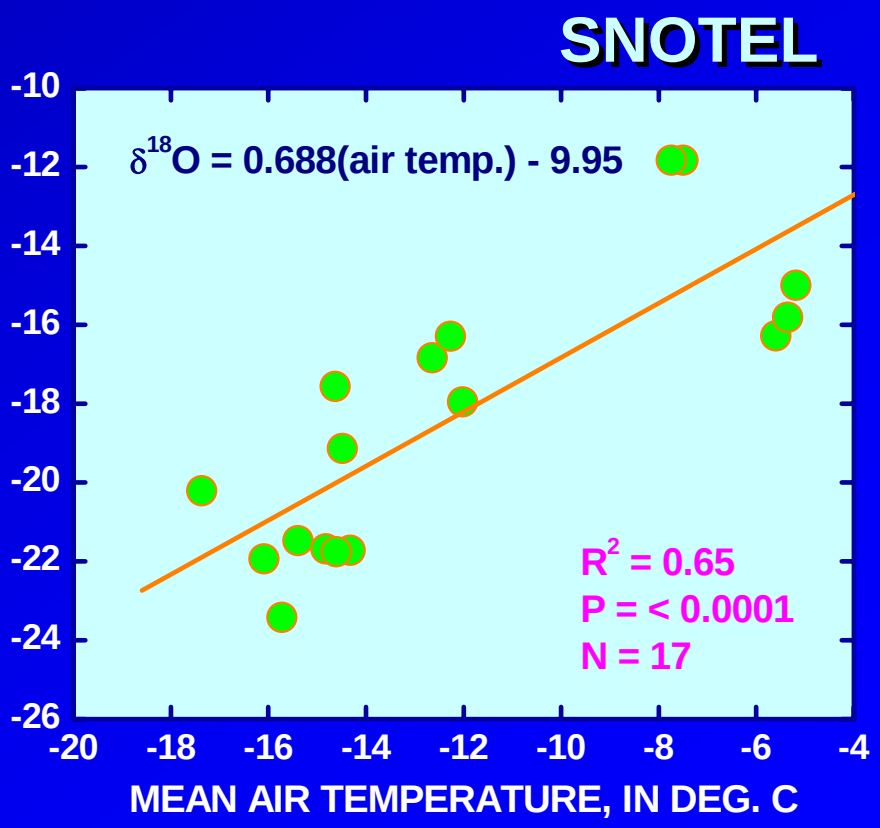
Still snowing. Food running low.

Break in weather. Fly out.



TRANSFER FUNCTION COMPARISON





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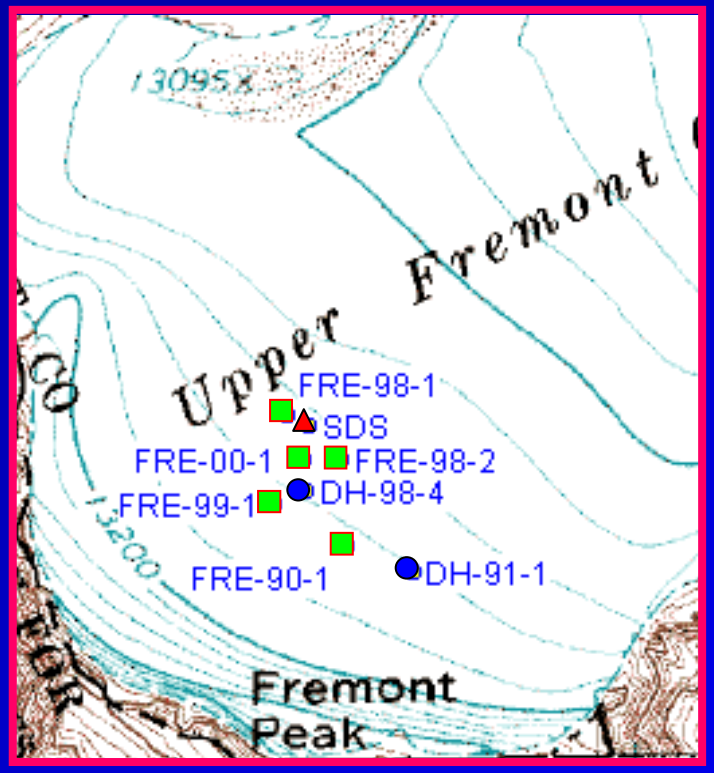
ICE-CORE RECORDS

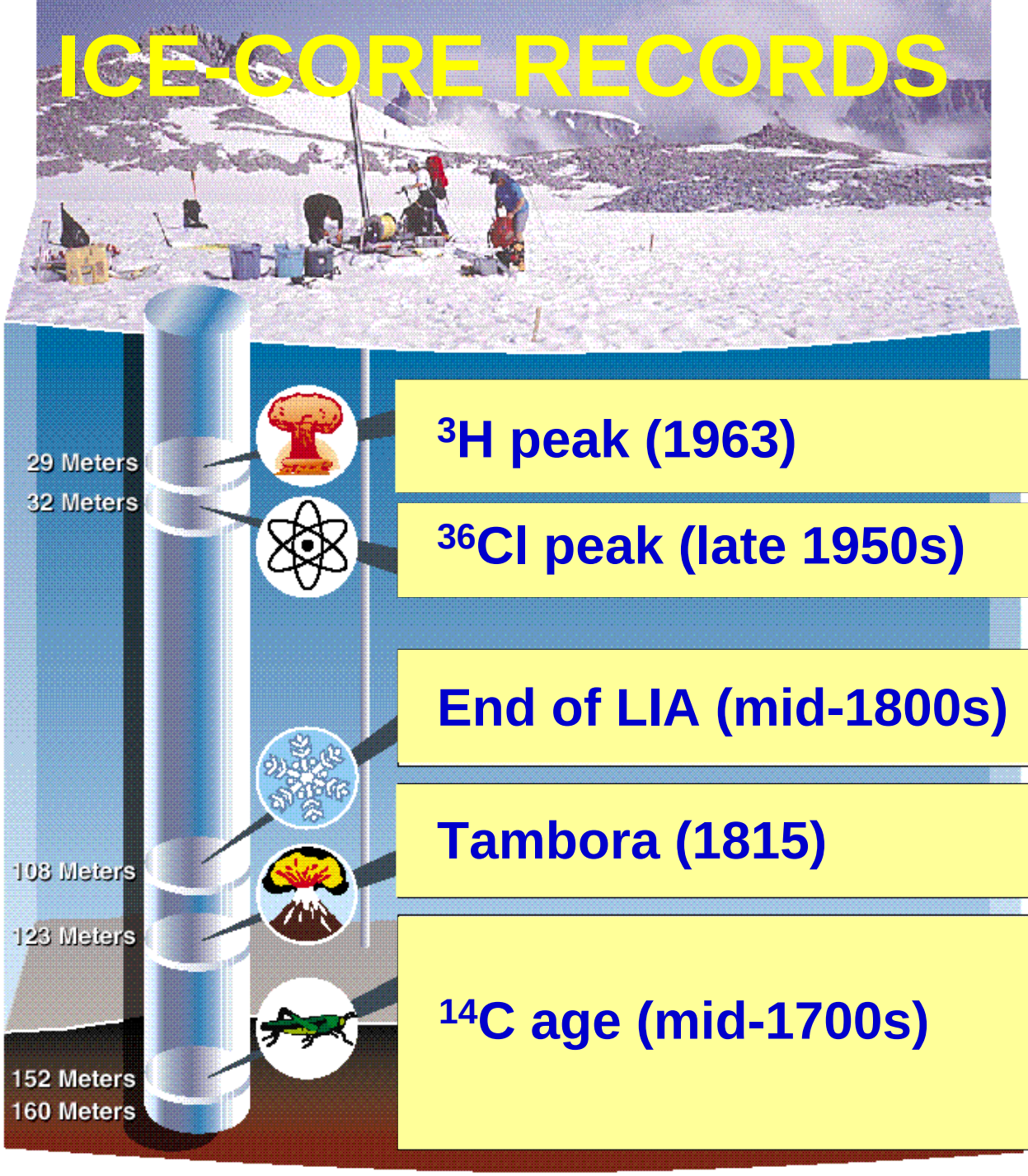
160-M ICE CORE COLLECTED IN 1998

DH-98-4



160-M ICE CORE COLLECTED IN 1991
DH-91-1

ICE-CORE RECORDS



^{3}H peak (1963)

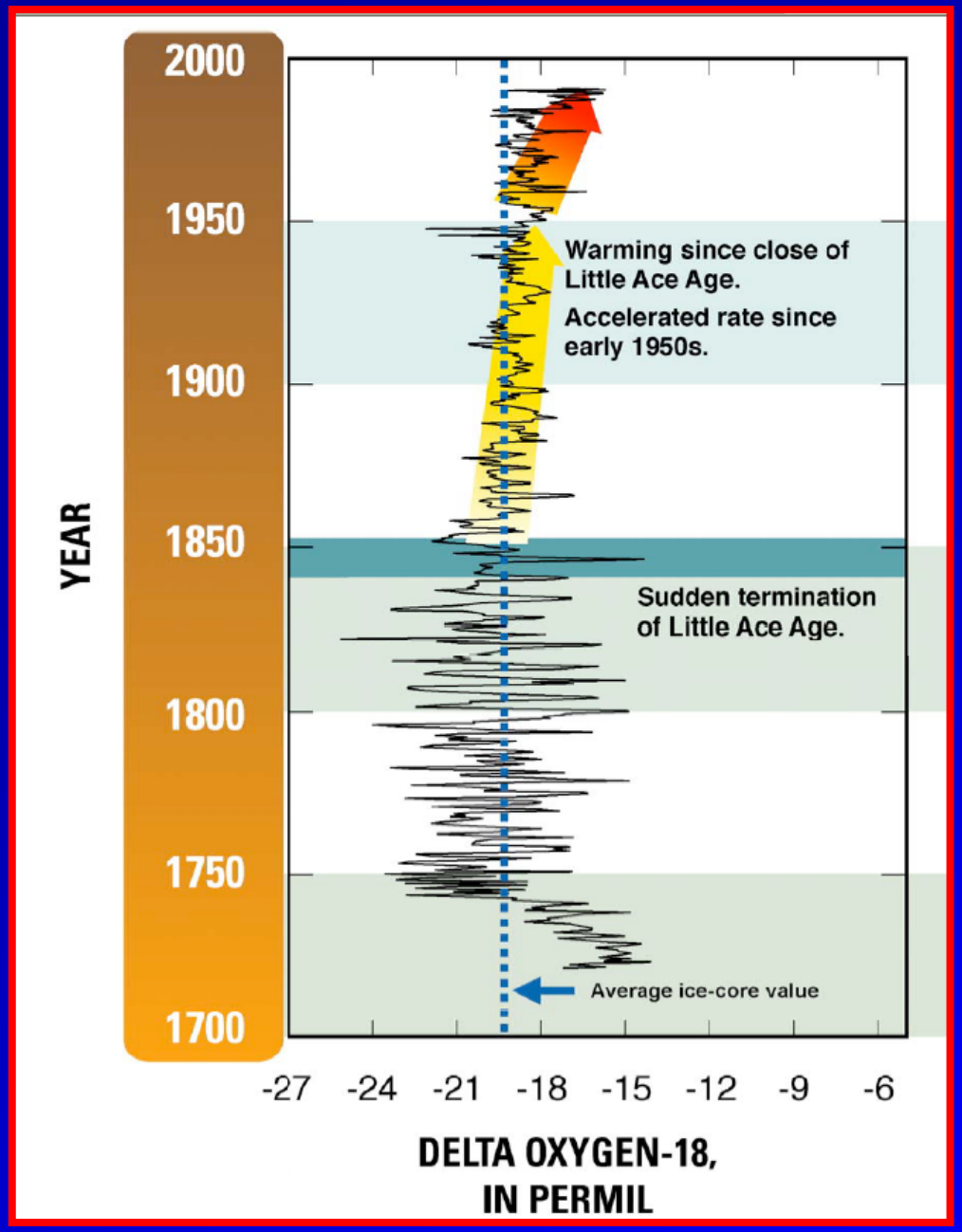
^{36}Cl peak (late 1950s)

End of LIA (mid-1800s)

Tambora (1815)

^{14}C age (mid-1700s)

SUDDEN TERMINATION OF LIA



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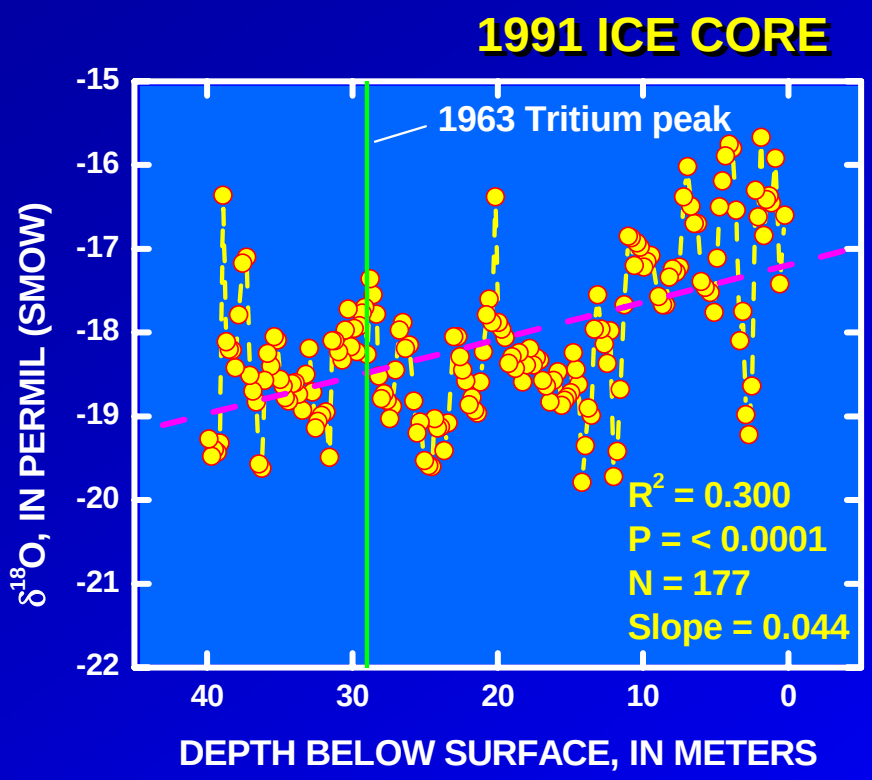
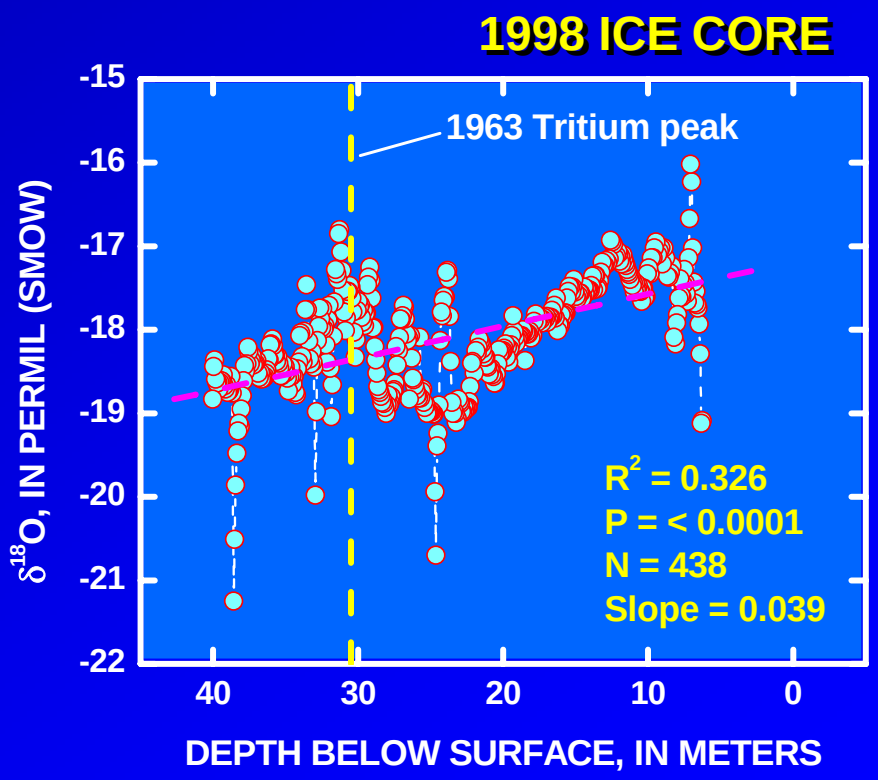
$\delta^{18}O$ PROFILES





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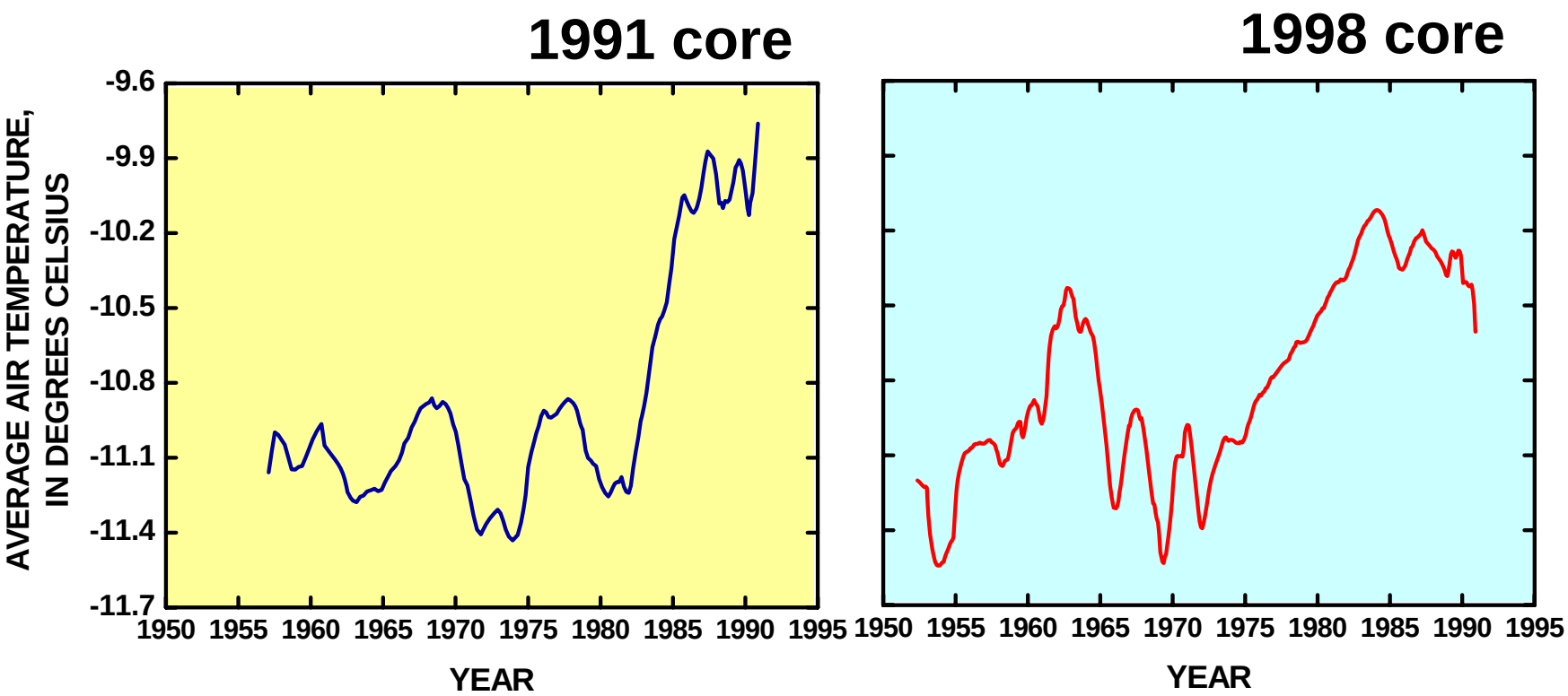
T_A RECONSTRUCTION



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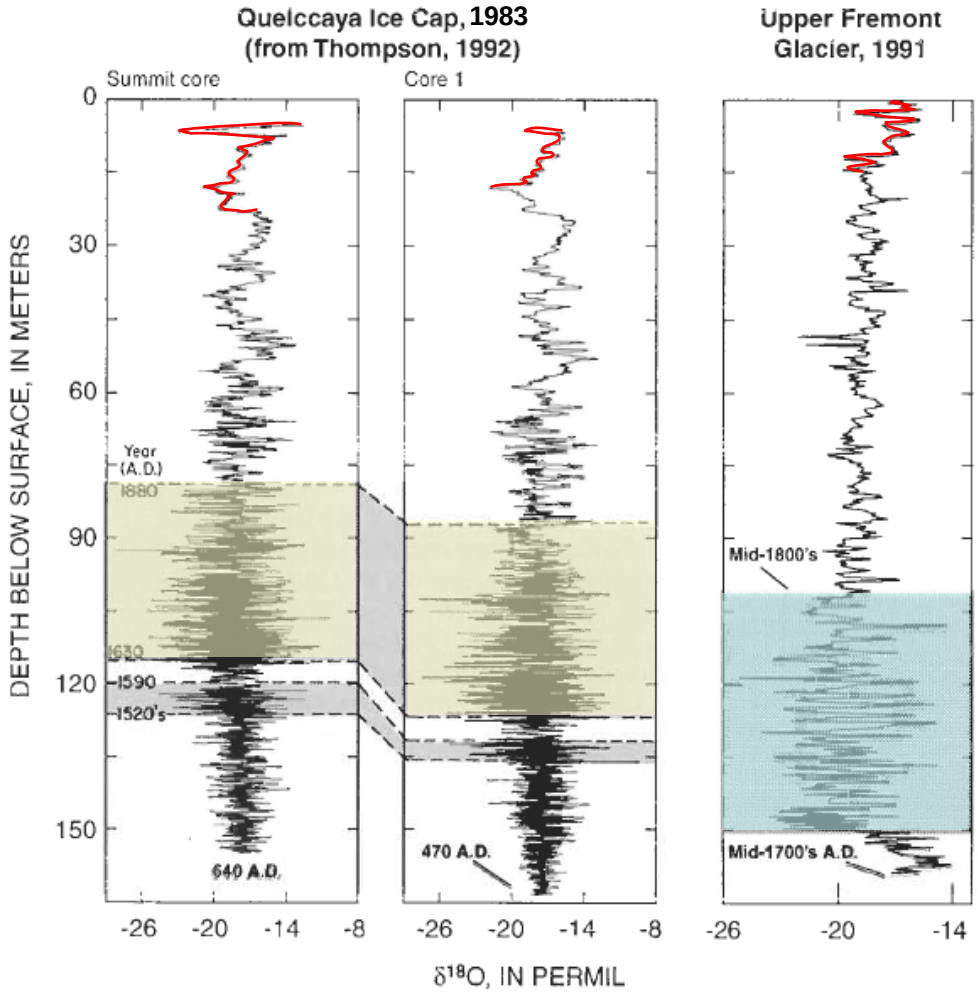
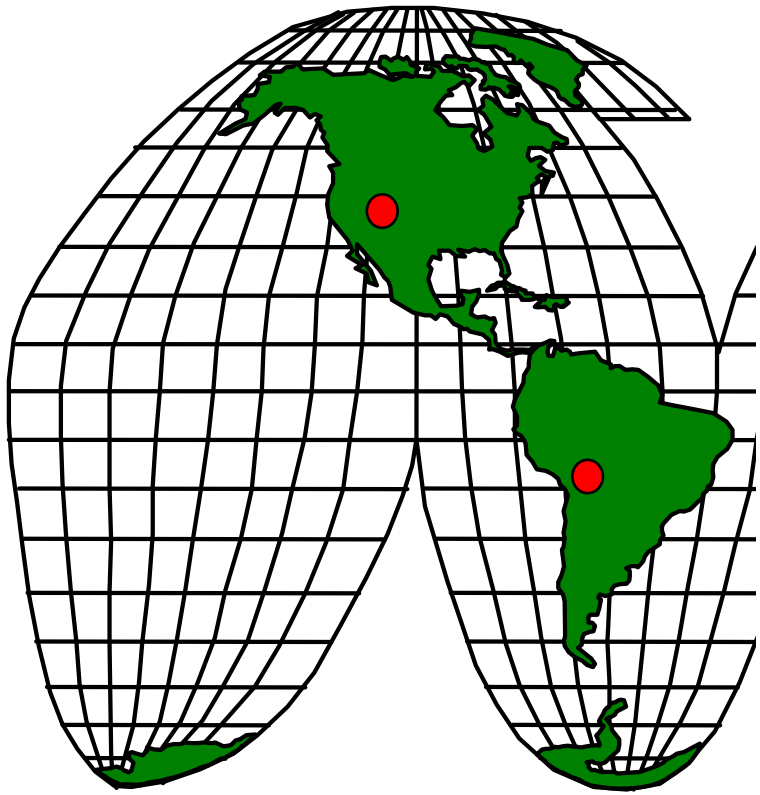
T_A RELATIVE TO LIA

Time period	Number of ice-core samples	Mean delta oxygen-18 ($\delta^{18}O$), in permil	Average air temperature (T_A), in degrees Celsius	Change in average air temperature relative to Little Ice Age, in degrees Celsius
1740 to 1845 A.D. (Little Ice Age)	220	-19.85	-12.1	0.0
1860 to 1950 A.D.	266	-19.00	-11.5	+0.6
1950 to 1991 A.D.	204	-18.16	-10.9	+1.2
1985 to 1991 A.D.	39	-16.99	-10.0	+2.1
1720 to 1991 A.D.	760	-18.90	-11.4	+0.7

OTHER SITES





EXPLANATION

Periods of increased annual variability identified in ice-core records from the Quelccaya Ice Cap

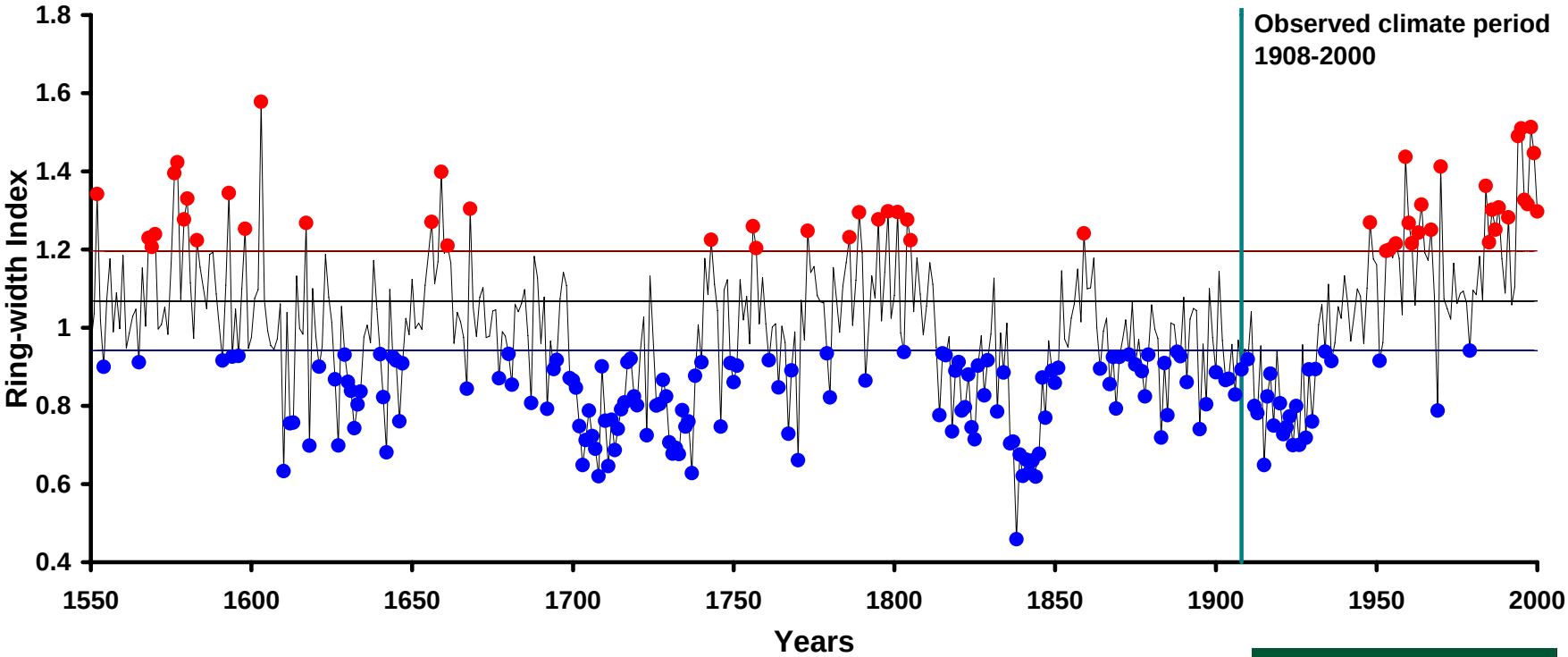
Section of high-amplitude oscillations identified in the Upper Fremont Glacier ice-core record

Fremont Glacier Study Team

TREE-RING DATA

Fremont Whitebark Pine Site Episodes			
Episodes	**Interpretation**	**#Quartile/ #Total Values**	**%**
1568-1583	Warm	8/16	50
1610-1647	Cool	20/38	53
1677-1751	Cool	48/75	64
1814-1936	Cool	74/123	60
1948-2000	Warm	24/53	45

Fremont Whitebark Pine Tree-ring Chronology
Waggoner, Graumlich and Hill (in prep)



Fremont Glacier Study Team

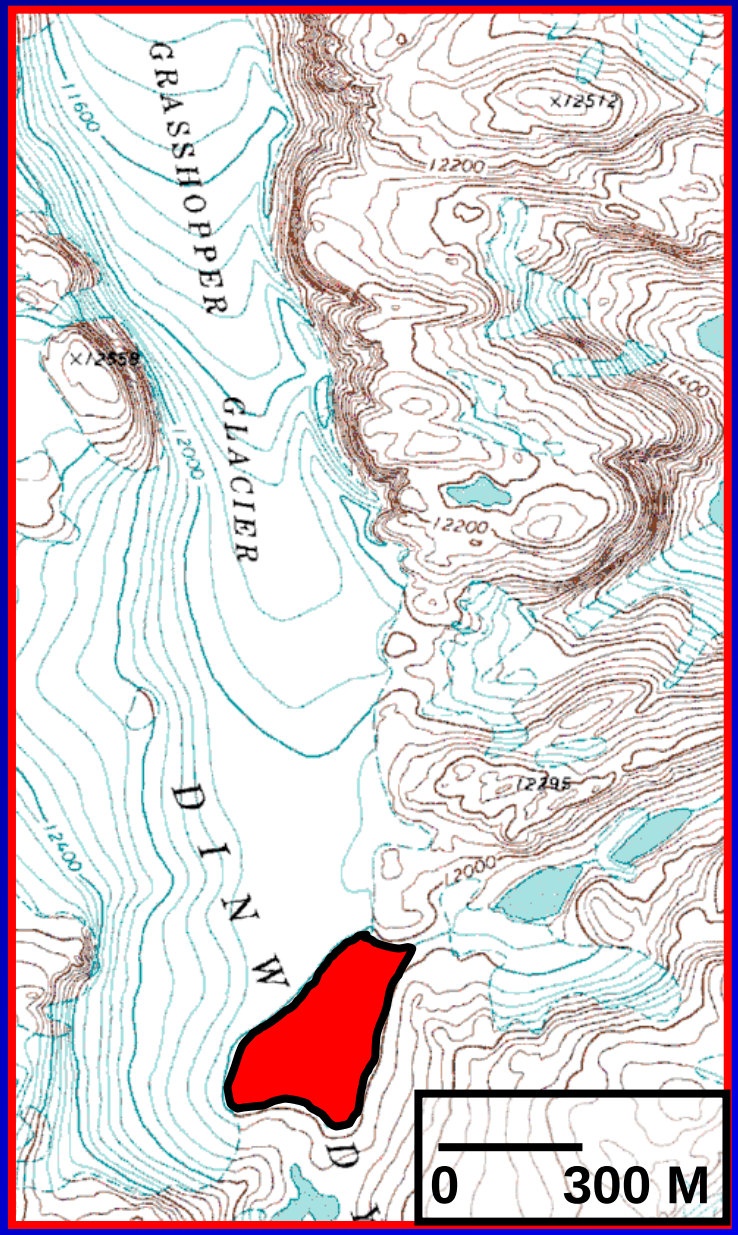
Salt Lake Tribune, 03/06/01

GLACIER RESPONSE TO WARMING?

Aftermath of flood event in 2003

Fremont Glacier Study Team

- Worldwide retreat and thinning of glaciers
- Exposure of unstable sediment
- Steep slopes
- Readily mobilized
- Recently documented by O'Connor et al., (2001)



WIND RIVER RANGE GLACIERS

- Largest extent of glacial ice in the Rocky Mountains within the continental U.S.
- Grasshopper Glacier: Ice dammed lake in headwall

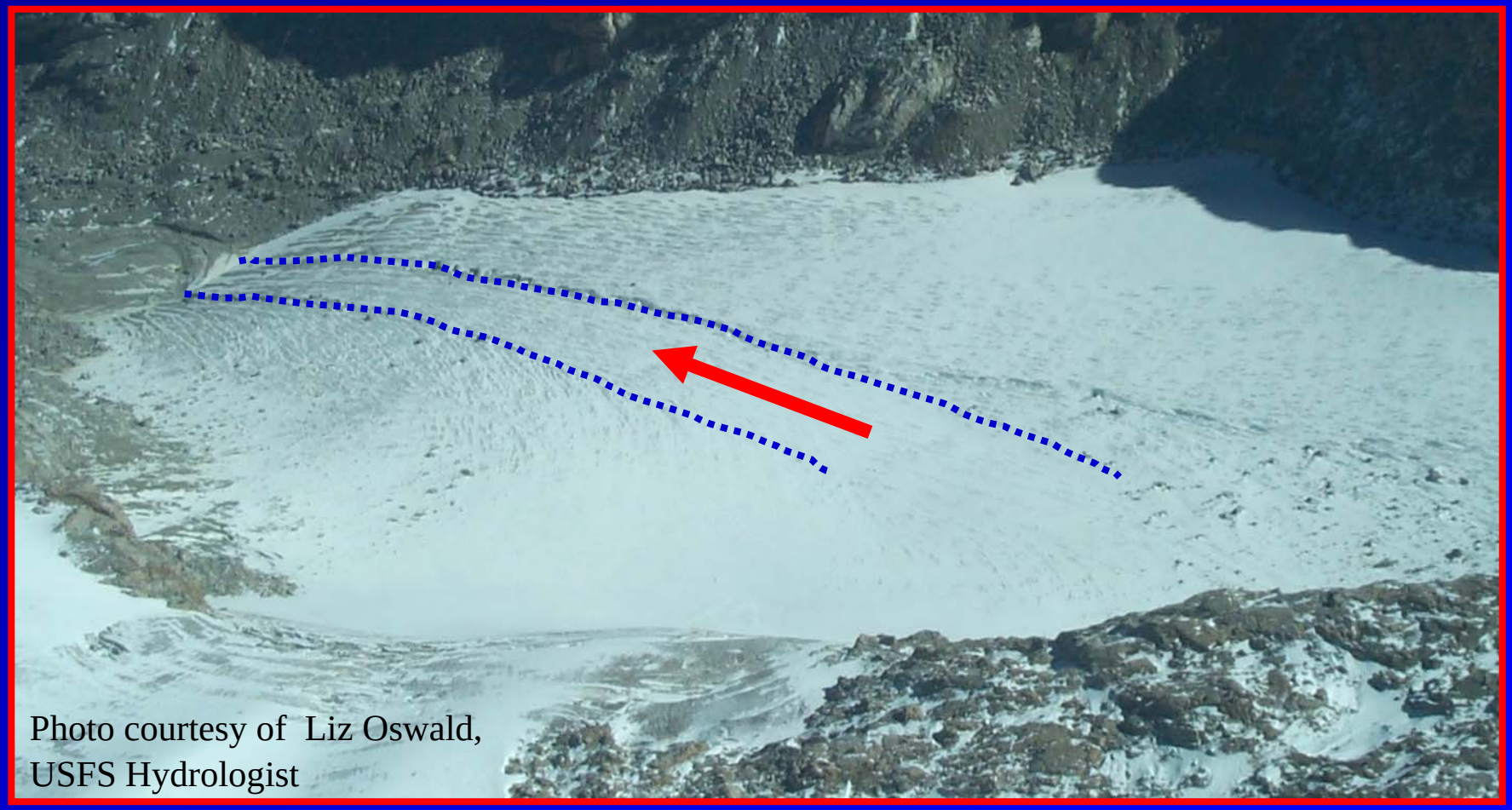
GRASSHOPPER GL. EVENT

Photo courtesy of Liz Oswald, USFS

Lake after dam failure (9/22/2003)

- Ice dam reduced by accelerated melting
- Flood initiated on or about 9/6/2003
- Lake equilibrates to lower level via catastrophic release
- Release of 2.5 million cubic meters of water

DOWNSTREAM IMPACTS

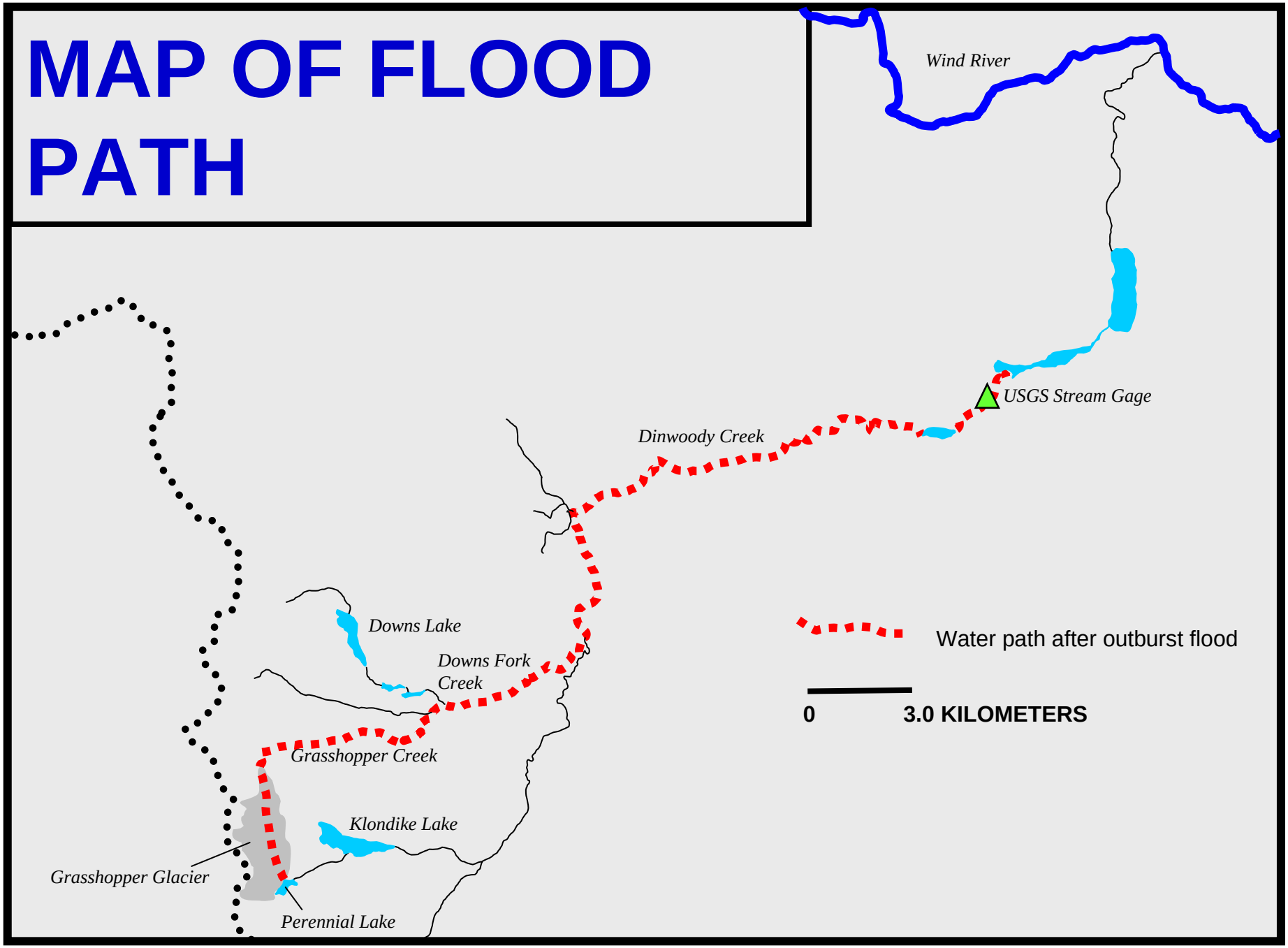


Flood channel on lower Grasshopper Glacier (9/22/2003)

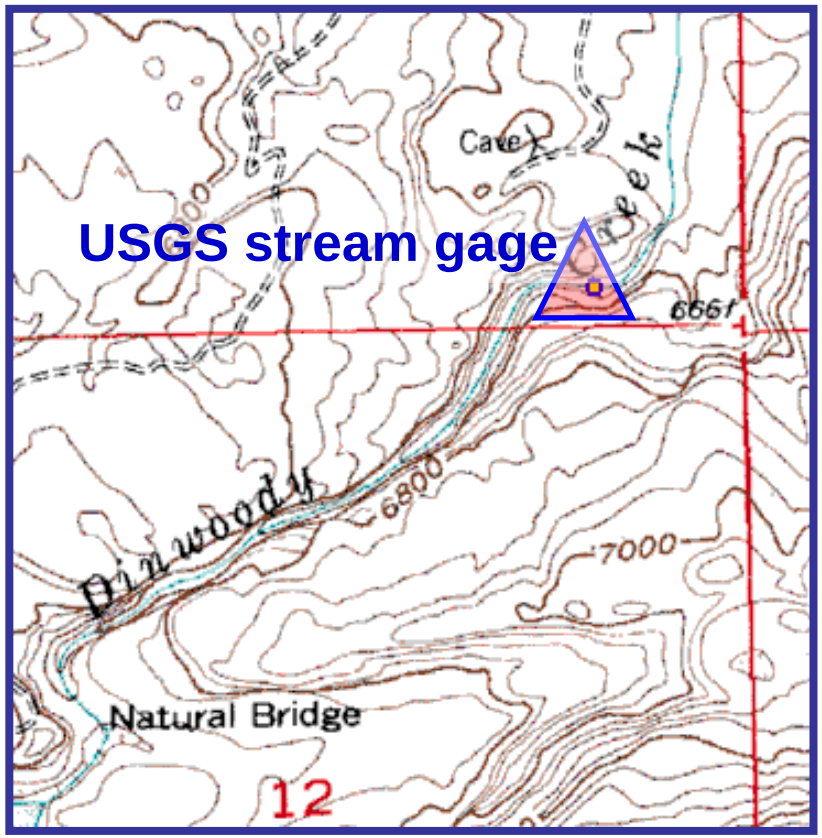
DOWNSTREAM IMPACTS

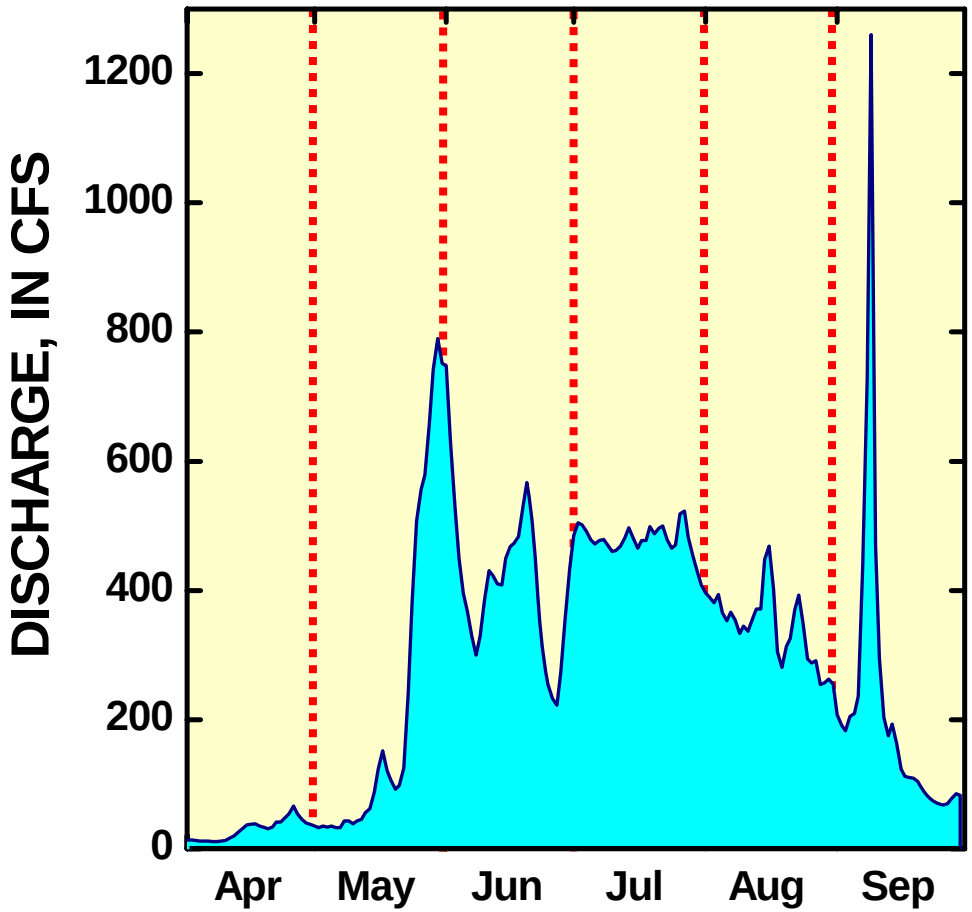
Flood deposits in Downs Fork Meadow (9/22/2003)

MAP OF FLOOD PATH



FLOOD DISCHARGE IN DINWOODY CREEK (32 km)





DINWOODY CREEK ABOVE LAKES, NEAR BURRIS, WY

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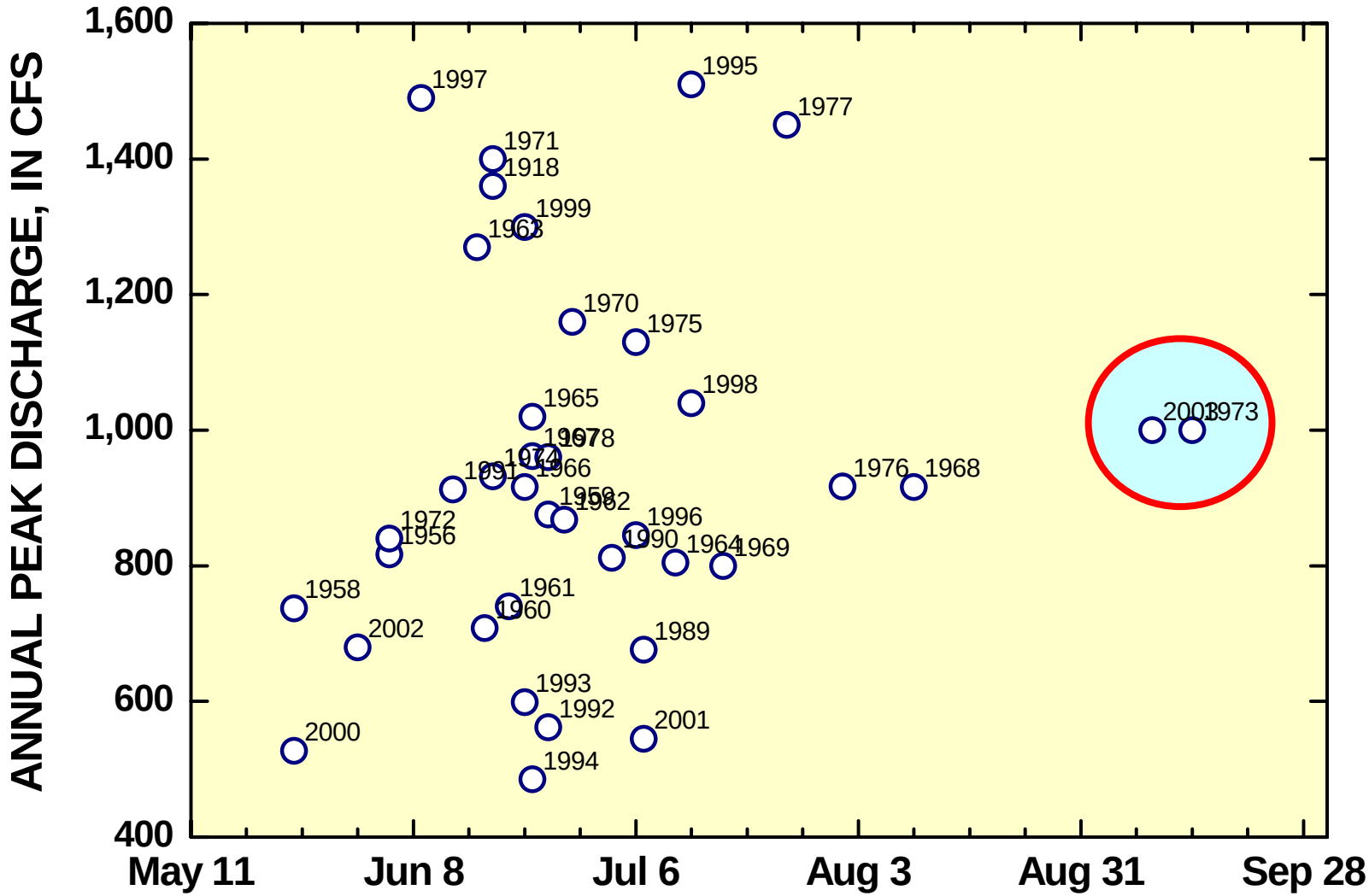
ANNUAL PEAK DISCHARGE



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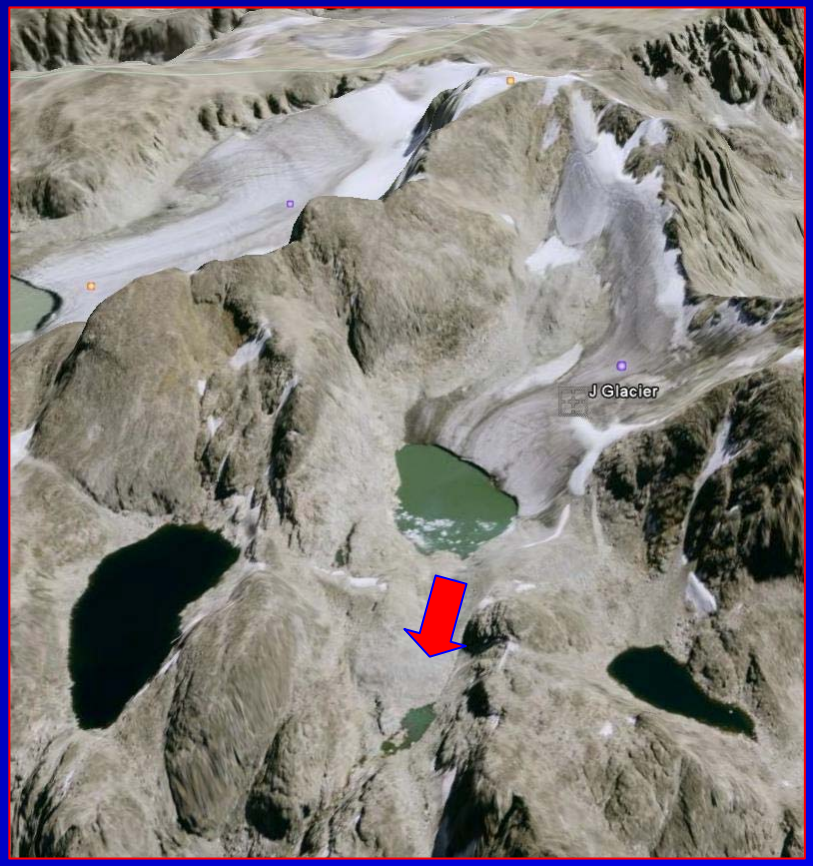
FUTURE FLOOD POTENTIALS

Photos from Google Earth

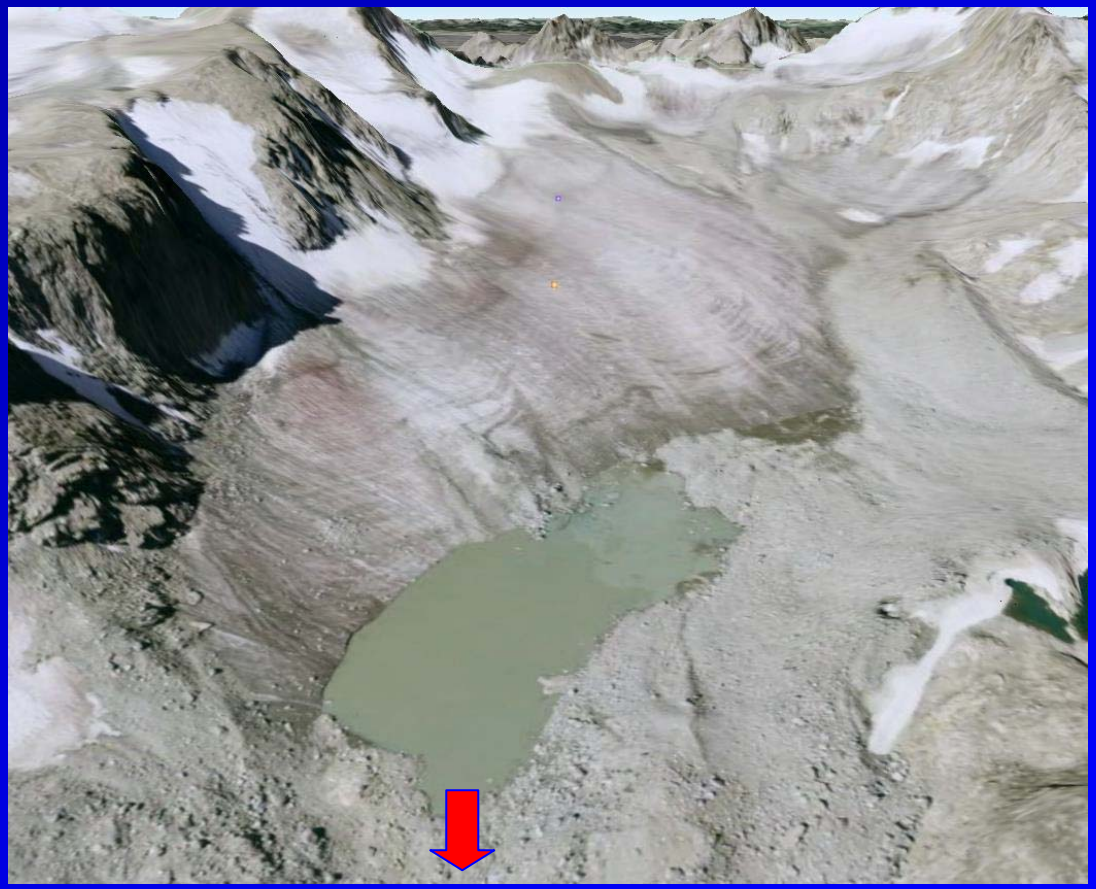


J Glacier

Minor Glacier

FUTURE FLOOD POTENTIALS

Photos from Google Earth



Sourdough Glacier

Sacagewea Glacier

Impact of NO_x and SO_2 emissions to USFS wilderness lands?

Pollution May Be Mystery Killer of Bighorns

BY GARY POLAKOVIC

LOS ANGELES TIMES

WIND RIVER MOUNTAINS, Wyo. — The baby bighorn sheep stumbled and collapsed on the stony tundra, too sick to keep up with its mother.

Jon Mionczynski, a wildlife researcher, had seen this before. For some reason, lambs born into the largest herd of bighorn sheep in the Rockies were not surviving.

It would be hard to find a safer sanctuary. But as scientists teamed up with Mionczynski to unravel the mystery, they learned that there is no such thing as pristine wilderness.

One evening, Mionczynski was close to capturing the lamb for testing, but the lamb and its mother started down the mountain and hunkered down in a fortress of boulders.

"I returned at daybreak and saw the ewe still guarding the site," Mionczynski recalled. "She made a low-pitched, throaty bleat. It just went right through me."

When he got to the boulders, he saw fresh mountain lion droppings. "The ewe had a torn ear, blood running down her face and claw marks on the side of her head," he said. "The lamb was gone."

In a way, the natural order had prevailed: the strong picked off the weak. But something was unnatural too: What was making lambs so sick within weeks of their birth?

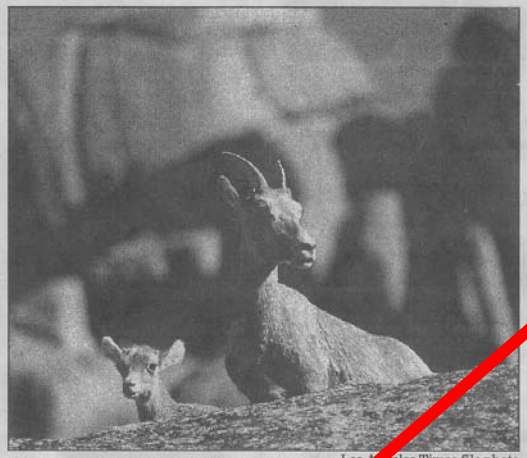
The herd, which used to number about 1,250, plummeted by 30 percent in two years during the early 1990s and never recovered. Only about two of every 10 lambs survives.

In 1998, the Wyoming Department of Game and Fish told Mionczynski to set up a one-man camp at nearly 12,000 feet and study the herd.

Now, four years into the project, scientists believe they are close to solving the mystery. What they have discovered suggests that profound environmental changes are beginning to ripple through the food chain and into the bodies of lambs. As a result, Mionczynski fears, these icons of wild America may be unable to survive in the wilds.

No sooner had Mionczynski set up camp on Middle Mountain in June 1998 than he observed many feeble lambs. Born healthy, they grew sick shortly after ewes made their annual spring migration to Middle Mountain to forage.

Working in a makeshift lab fitted into a cave in the boulders, Mionczynski began testing plants the sheep eat. He discovered that selenium, a nutrient, had dipped to alarmingly low levels.



Los Angeles Times file photo

Researchers suspect air pollution may be causing the puzzling deaths of bighorn sheep such as these in the Rockies.

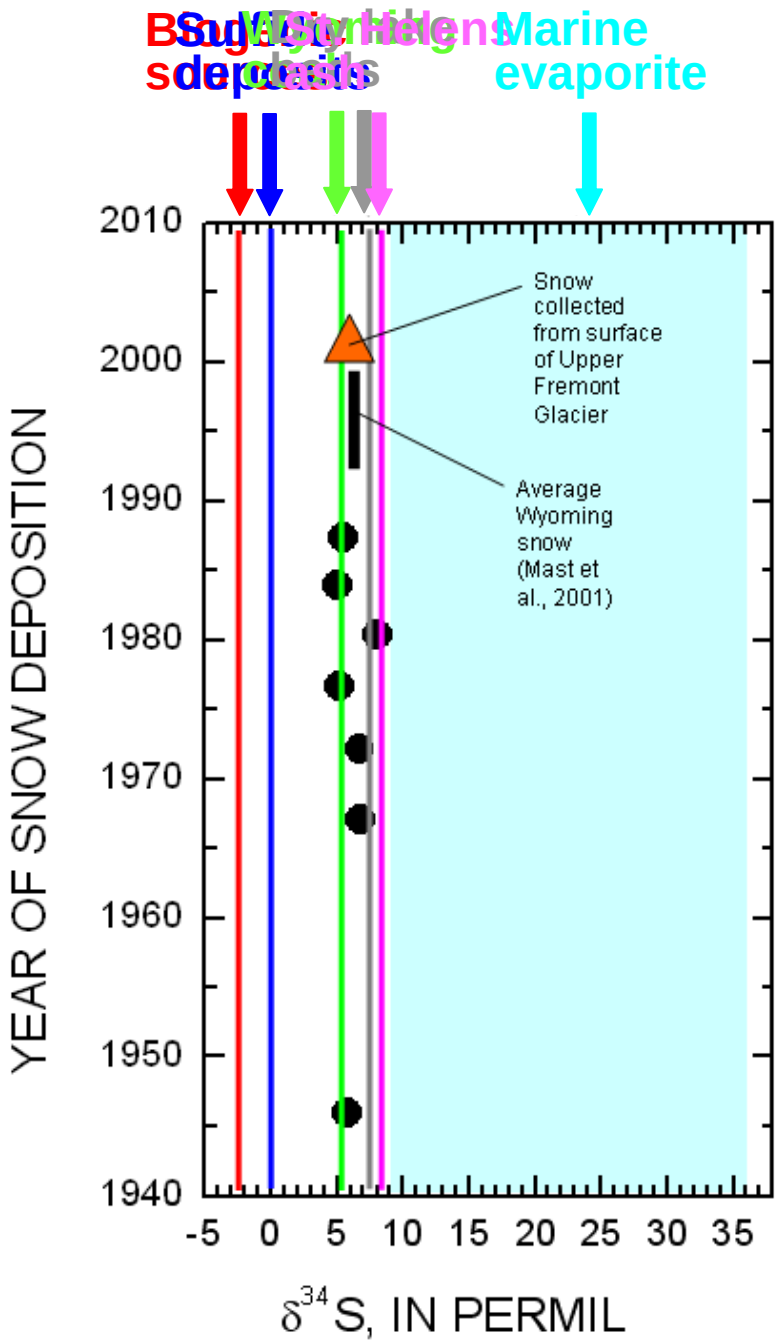
For at least a decade, according to scientists, storms have been carrying larger and larger amounts of chemical contaminants and dumping them across the Rockies. Among the chemicals are nitrates and ammonium, which can saturate the environment's natural nutrients or create acidic conditions similar to those that plague forests in the Northeast and Canada.

"Urbanization and sheep deaths seem to go hand in hand. We know there's a lot of acidification of the front range of the Rockies, and this offers a perfectly reasonable and clear mechanism. It's a hypothesis, but it's very plausible," said Rob Roy Ramey, chairman of zoology at the Denver Museum of Nature and Science.

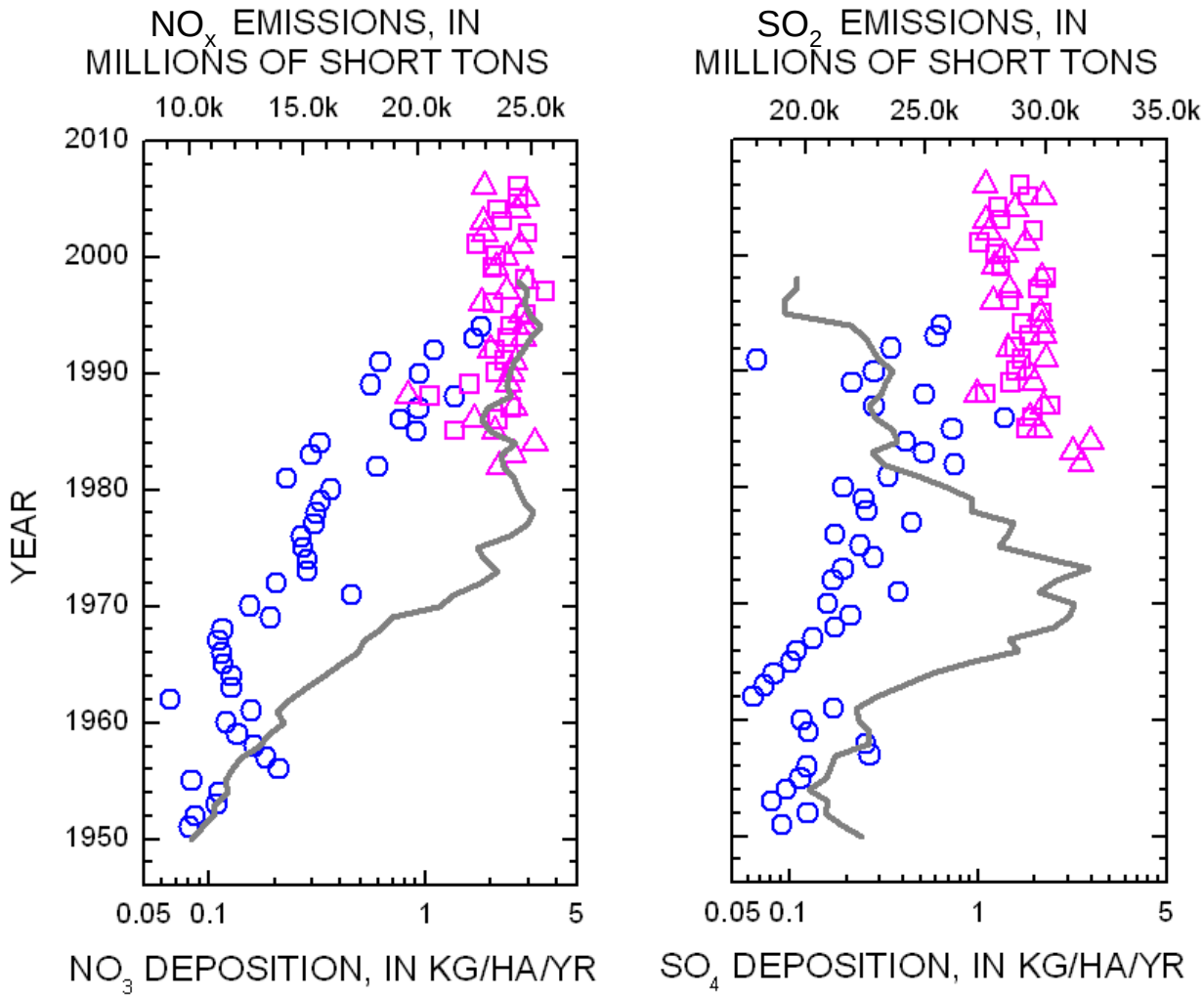
"….storms have been carrying larger and larger amounts of chemical contaminants and dumping them across the Rockies…."

Salt Lake Tribune, 9/8/2001

Isotopic fingerprints of SO_2 sources in precipitation, Northern Rocky Mountains



Extending the NADP record of S and N deposition, Northern Rocky Mountains



EXPLANATION

- Ice core
- WY 98
- WY 06
- U.S. emissions

Fremont Glacier Study Team

WHAT WE LEARNED

- Site-specific transfer functions developed
- Ice cores used to reconstruct high elevation temperature, nitrate, sulfate, bomb pulse, and mercury records
- Wear life vests when camping below rapidly melting glaciers
- Never second guess a pack goat

28 years later……