

Floods and Debris Flows in the Catalina Front Range

July 31, 2006



Bob Webb, Peter Griffiths, Chris Magirl, and Diane Boyer, USGS
Erik Pytlak, Craig Shoemaker, and Michael Schaffner, NWS
Phil Pearthree and Ann Youberg, Arizona Geological Survey

The Extreme Precipitation Event of July 31, 2006, and Its Effects

- In the early morning hours of July 31, following 4 days of rain, pulses of rainfall from mesoscale convective thunderstorms fell on the southern Santa Catalina and western Rincon Mountains.
- Record floods occurred in Rincon Creek, Pantano Wash, Tanque Verde Creek, Sabino Creek, and Rillito Creek.
- What was really spectacular, though, was what happened in Sabino Canyon and other nearby watersheds in the Front Range of the Santa Catalina Mountains.

GOES Water Vapor Imagery from July 31, 2006

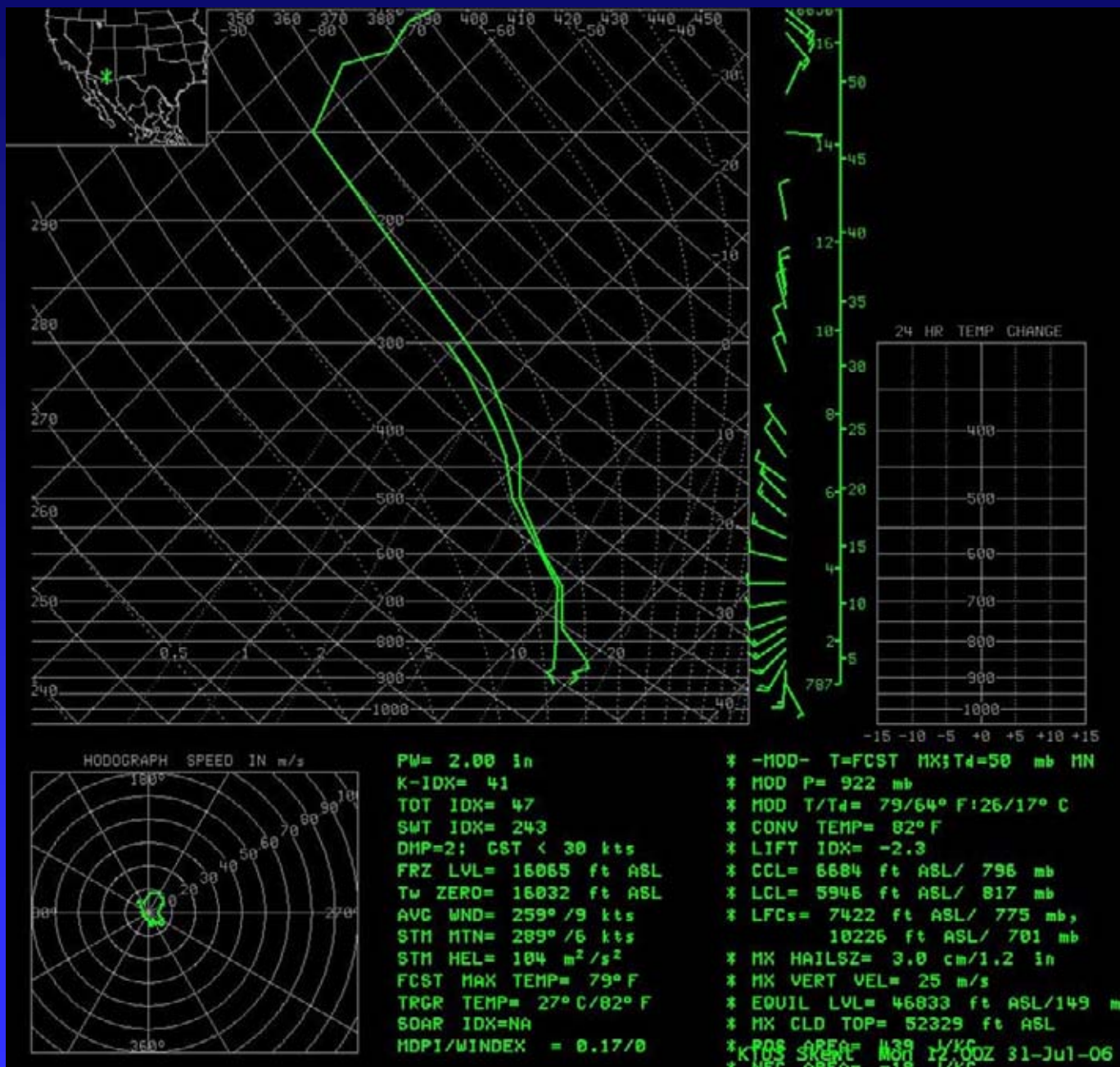


Upper-level low-pressure system over New Mexico steered moisture into southern Arizona over a five-day period.

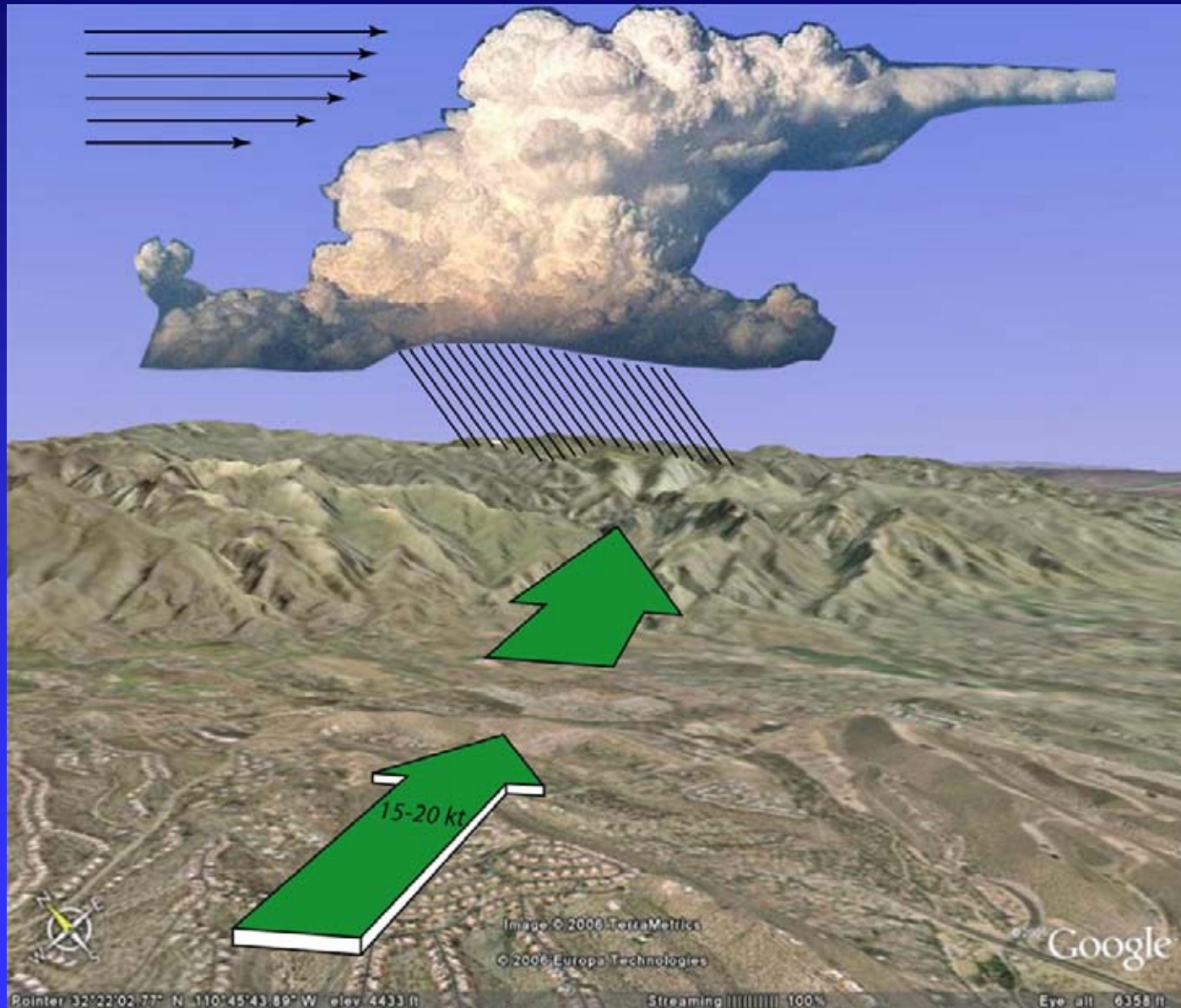
Early in the morning on July 31, a series of thunderstorms moved southwards from the Phoenix area through northeastern Pima County.

Half-hour images; white indicates high atmospheric water content

Morning Weather Balloon Sounding on July 31, 2006

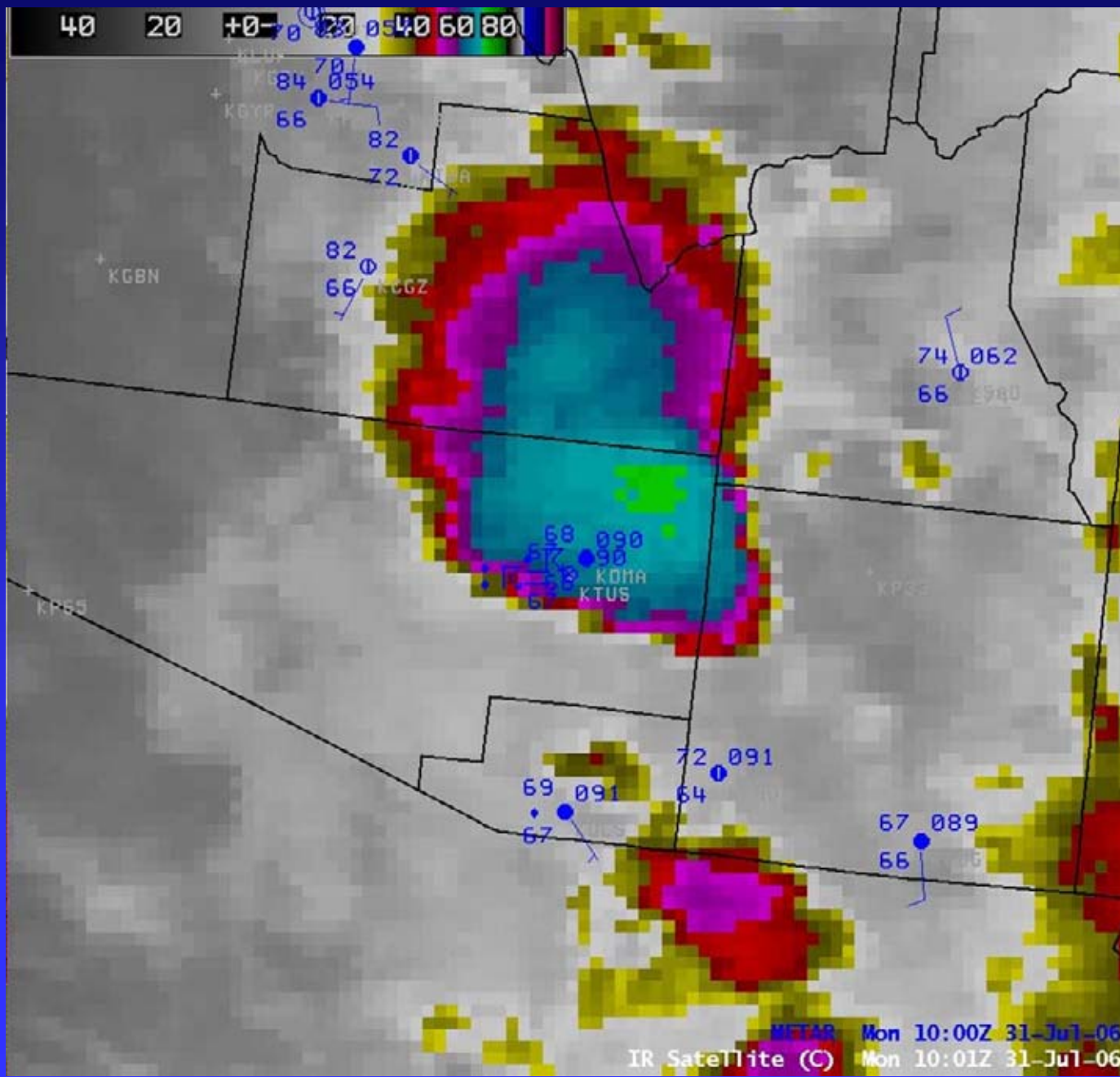


Upper-Level Shear From Northwest; Lower-Level Jet from Southwest

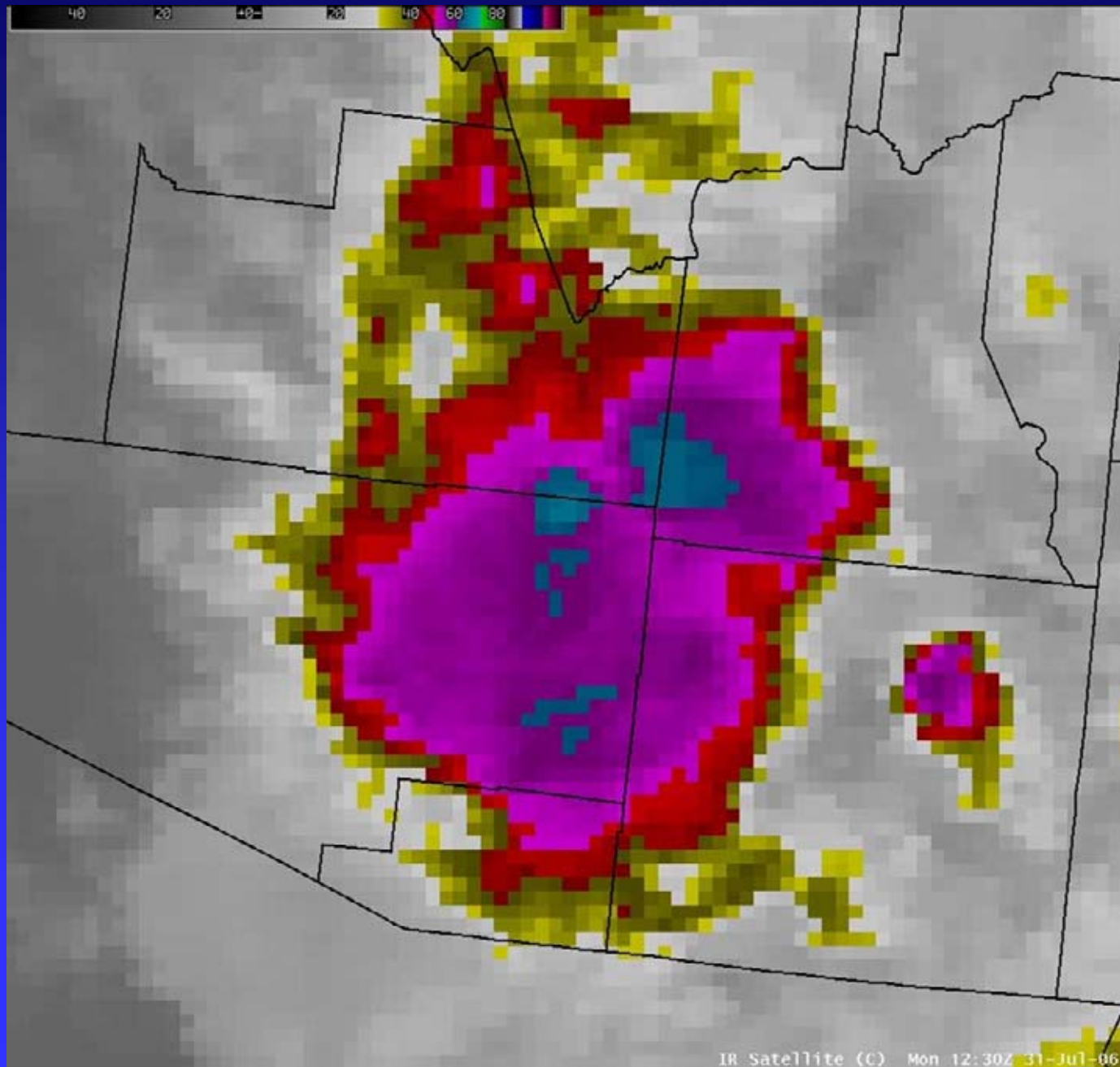


Wind and water vapor movement was like a firehose aimed straight up over Sabino Canyon and other Santa Catalina Mountain tributaries the morning of July 31.

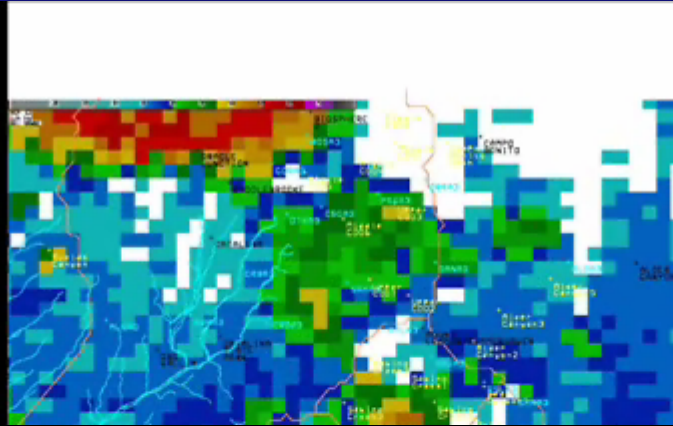
First Punch: Cold-Top Mesoscale Thunderstorm



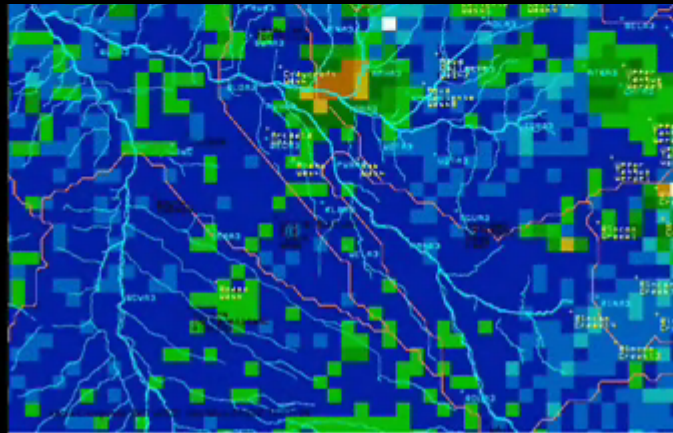
Second Punch: Warm-Top Mesoscale Thunderstorm



Composite NEXRAD Weather Radar, July 31, 00:00 – 08:00

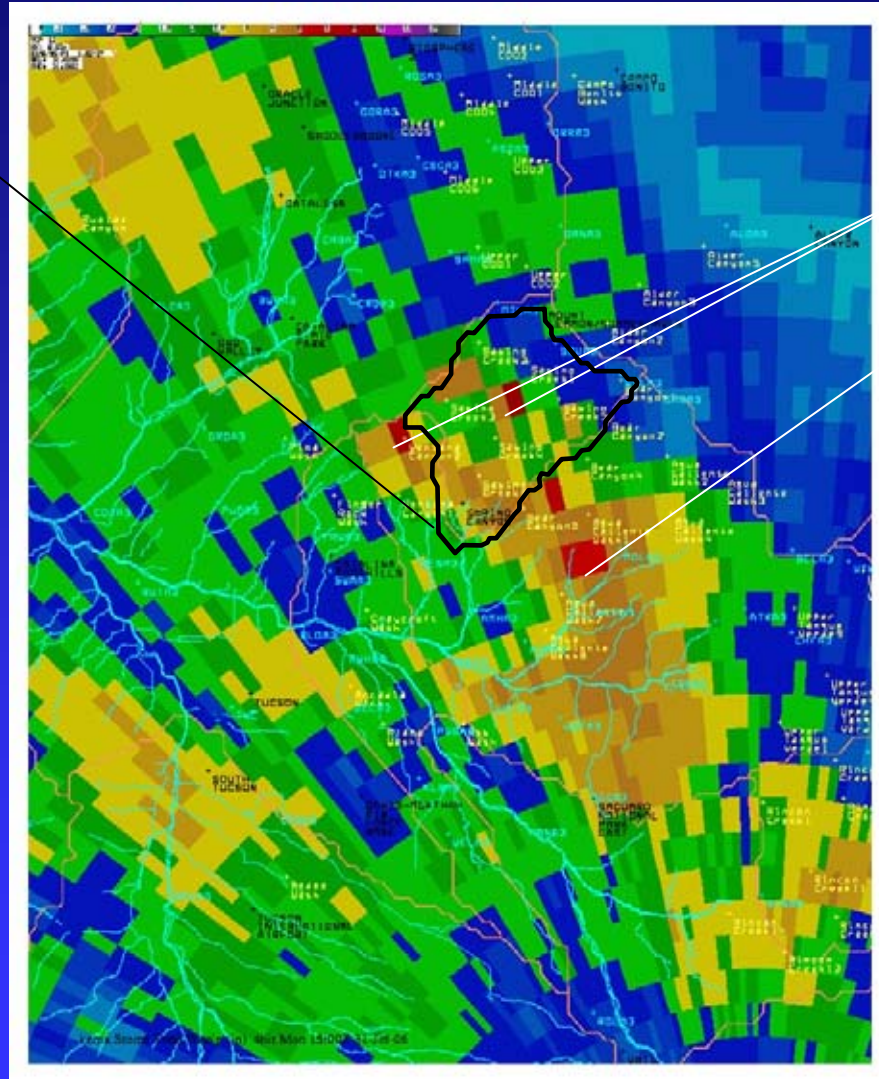


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Total Storm Precipitation from NEXRAD Weather Radar

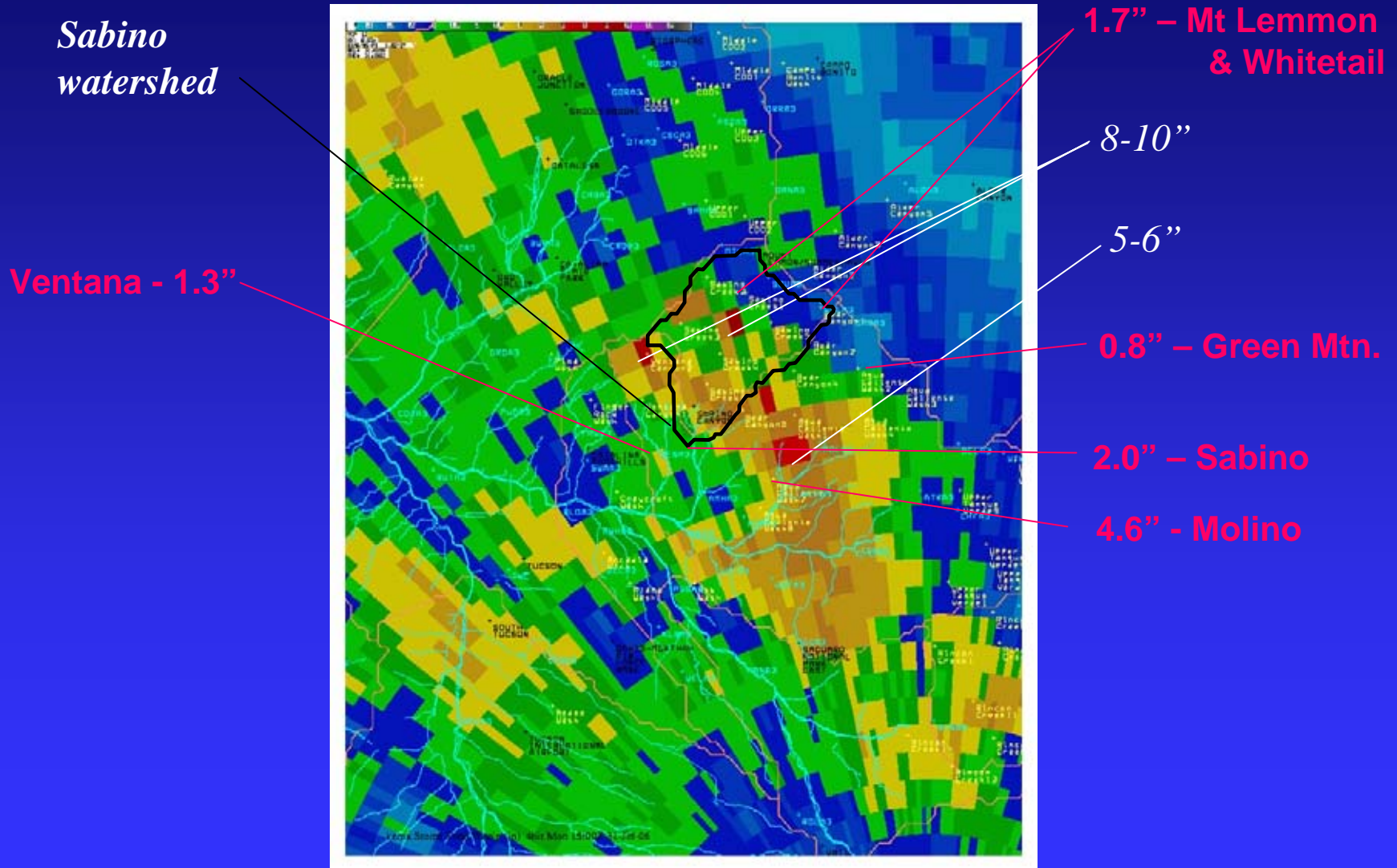
Sabino watershed



8-10"

5-6"

Total Storm Precipitation from NEXRAD Weather Radar and ALERT Rain Gages



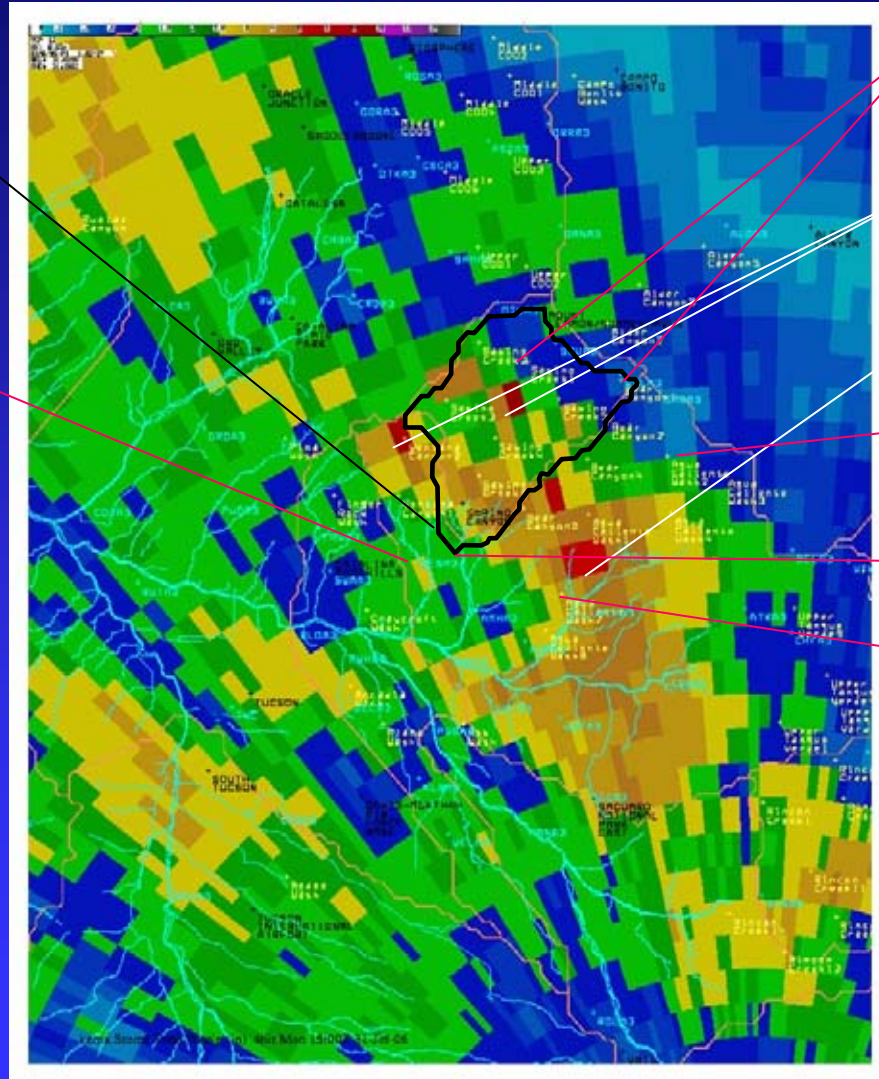
Total Storm Precipitation from NEXRAD Weather Radar and ALERT Rain Gages

*Sabino
watershed*

Ventana - 1.3"

ALERT System
Peak Storm
Intensities
(in/hr)

Mt. Lemmon	0.4"
Whitetail	0.5"
Green Mtn.	0.3"
Ventana	0.5"
Sabino	0.5"
Molino	1.4"



**1.7" – Mt Lemmon
& Whitetail**

8-10"

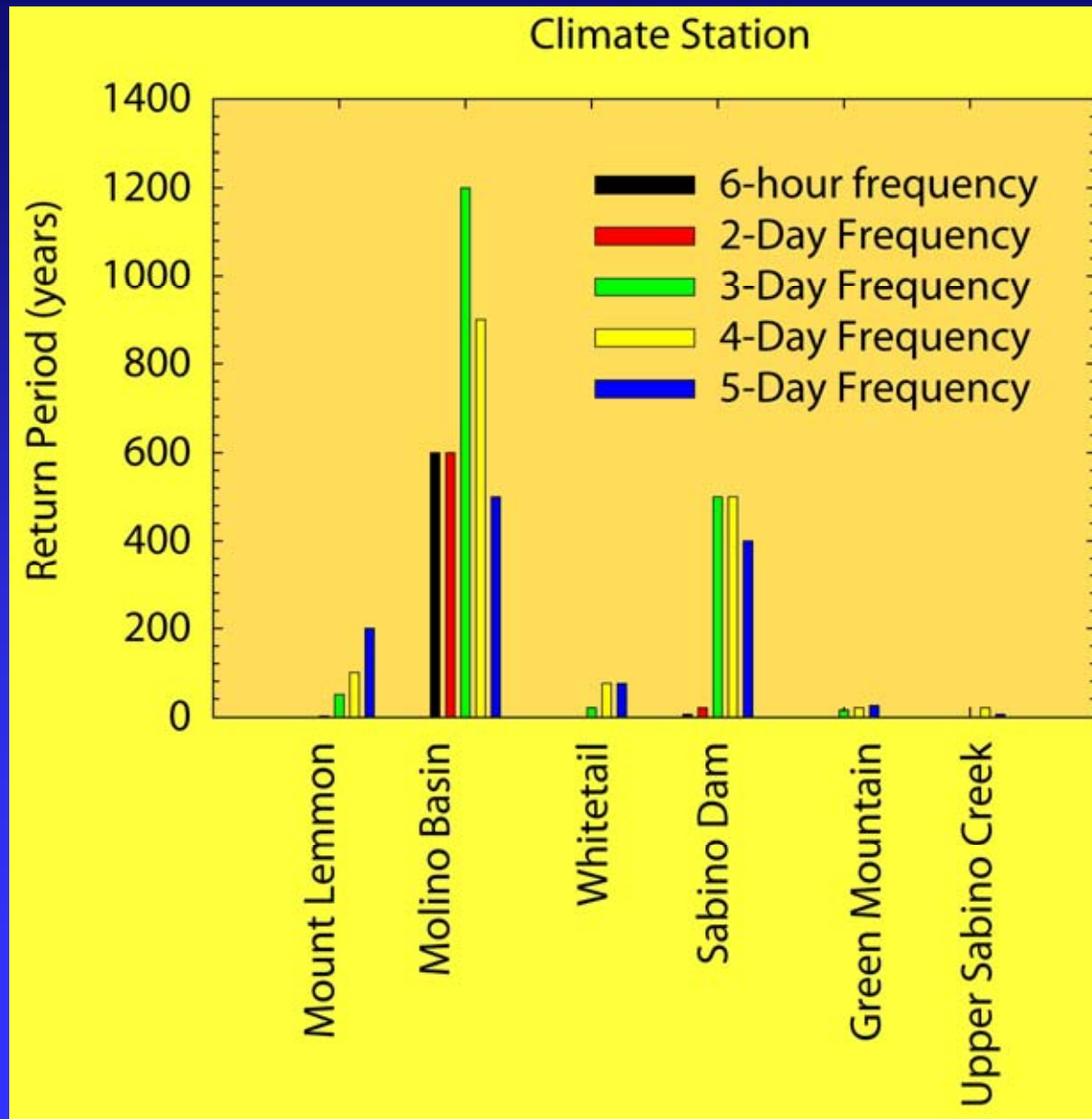
5-6"

0.8" – Green Mtn.

2.0" – Sabino

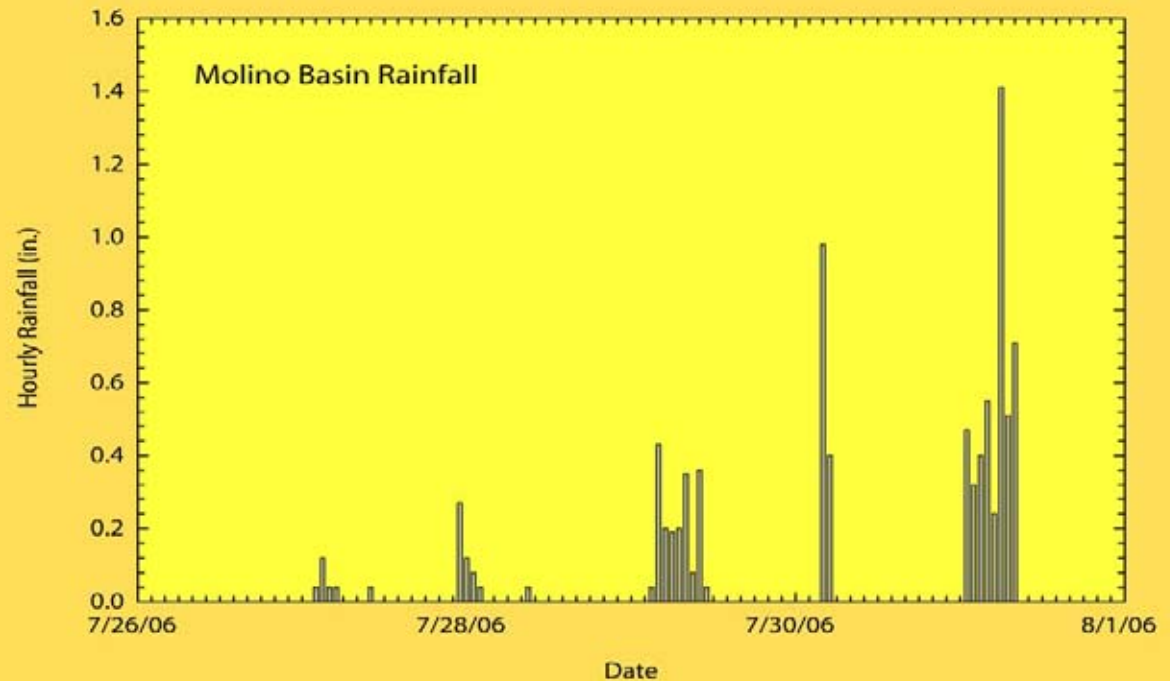
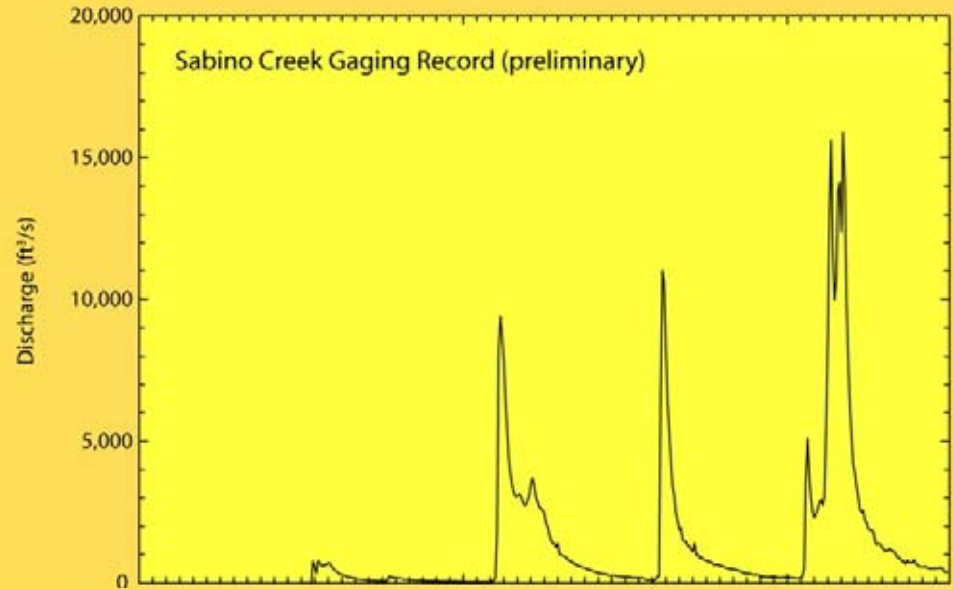
4.6" - Molino

What is Impressive is the Multi-Day Storm Return Periods



Streamflow and Precipitation

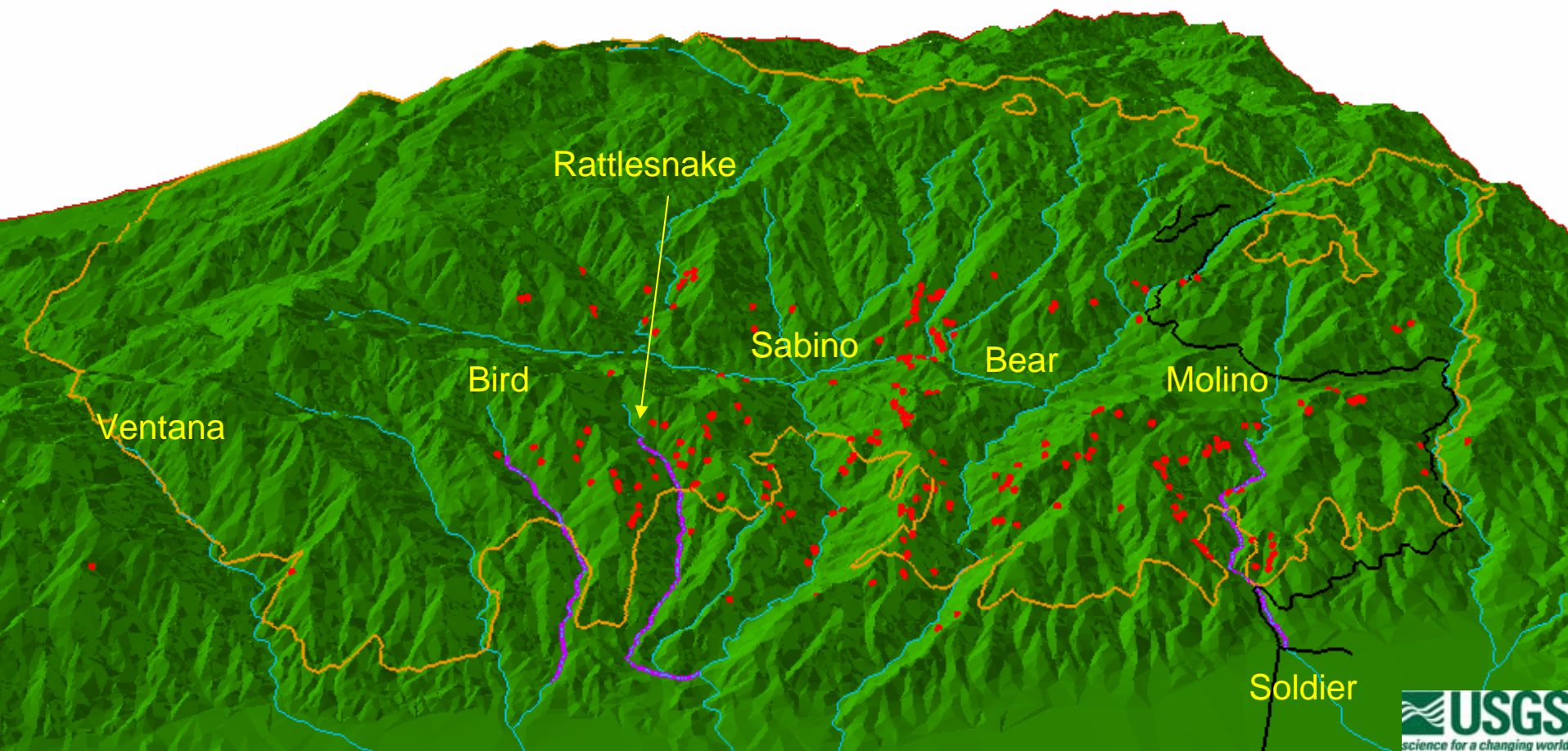
July 26-July 31



Debris Flows in the Catalina Front Range

Preliminary n = 240 slope failures

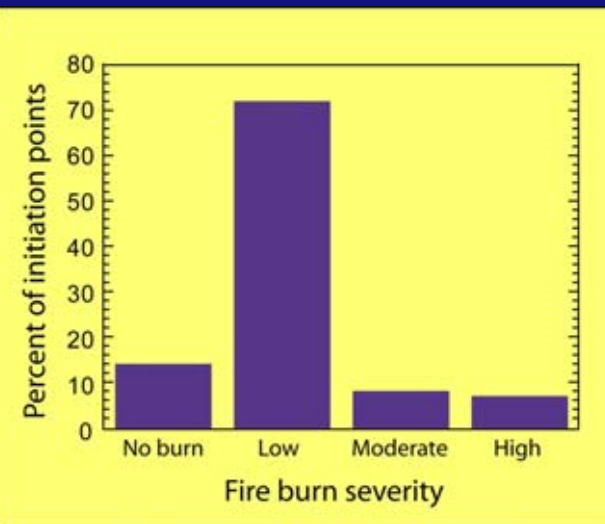
Most failures are between 4,000 – 6,000 feet elevation



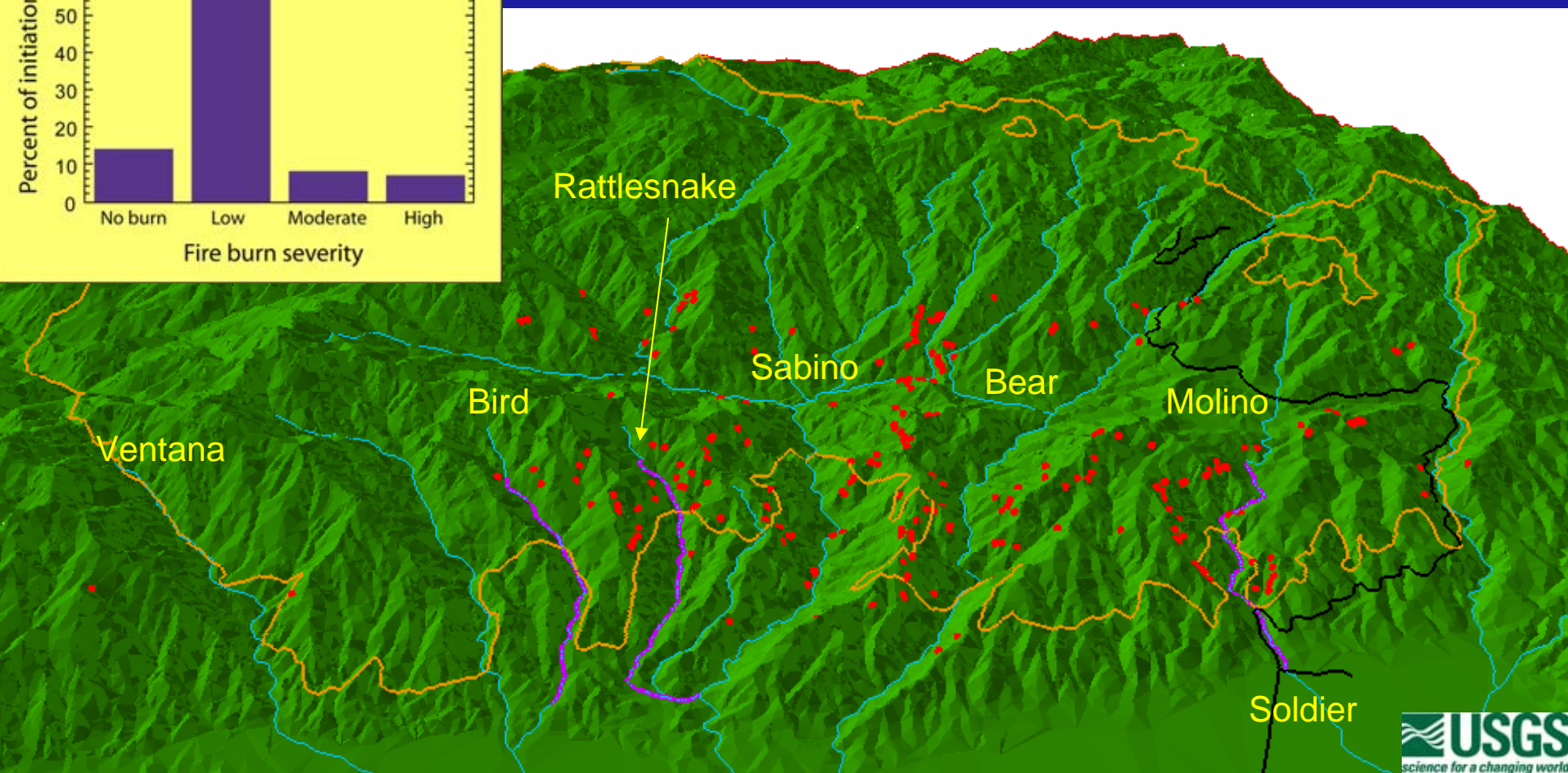
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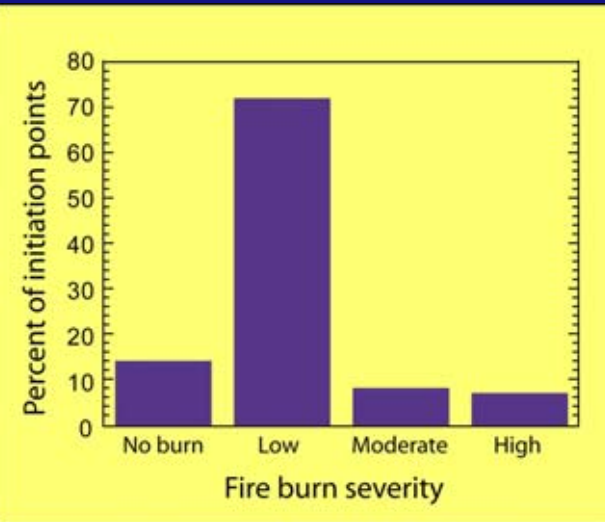
86% of failures were in areas little affected by the 2003 Aspen Fire



Debris Flows in the Catalina Front Range

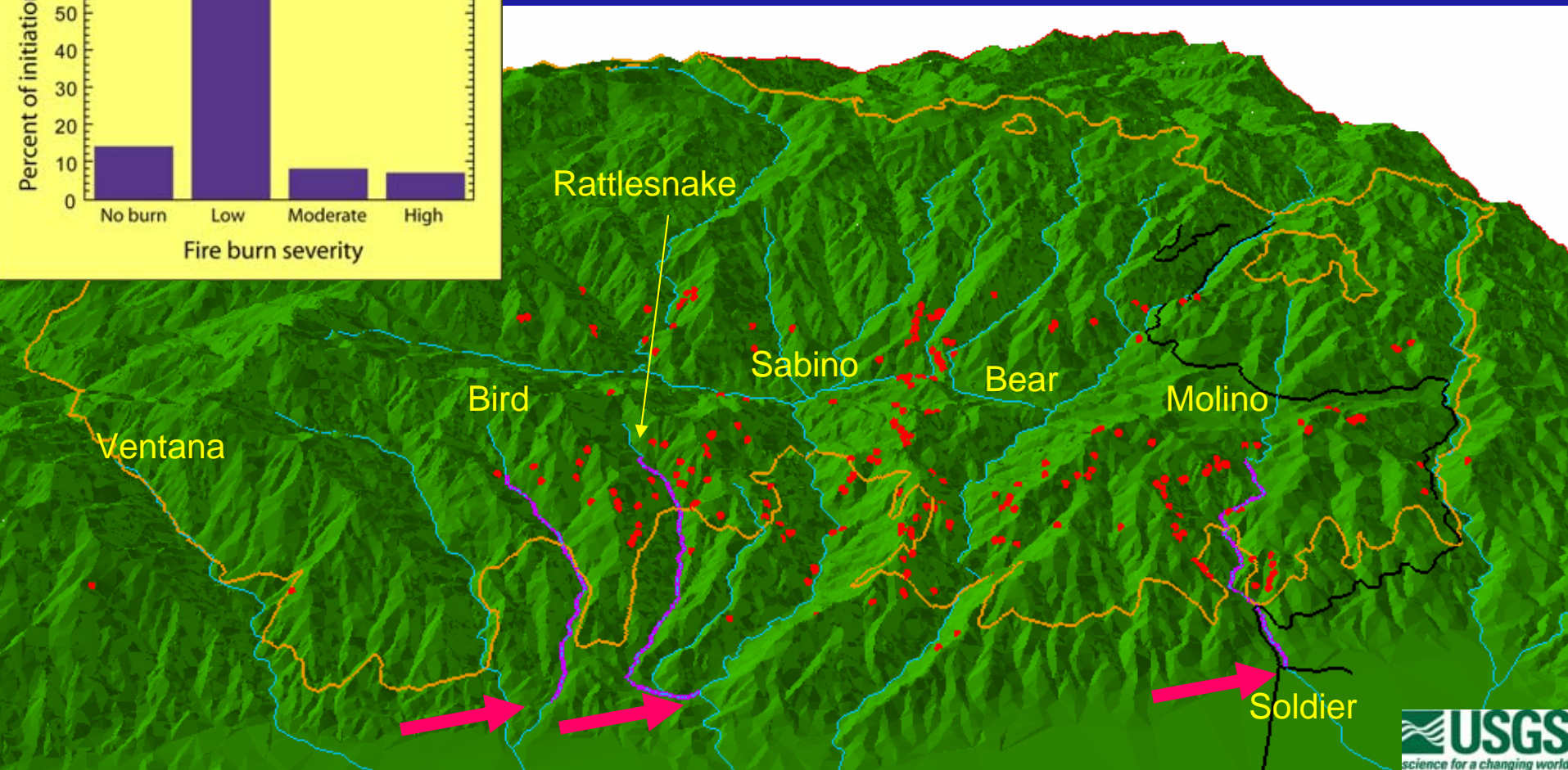
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86% of failures were in areas little affected by the 2003 Aspen Fire

Three debris flows made it to or close to the mountain front.

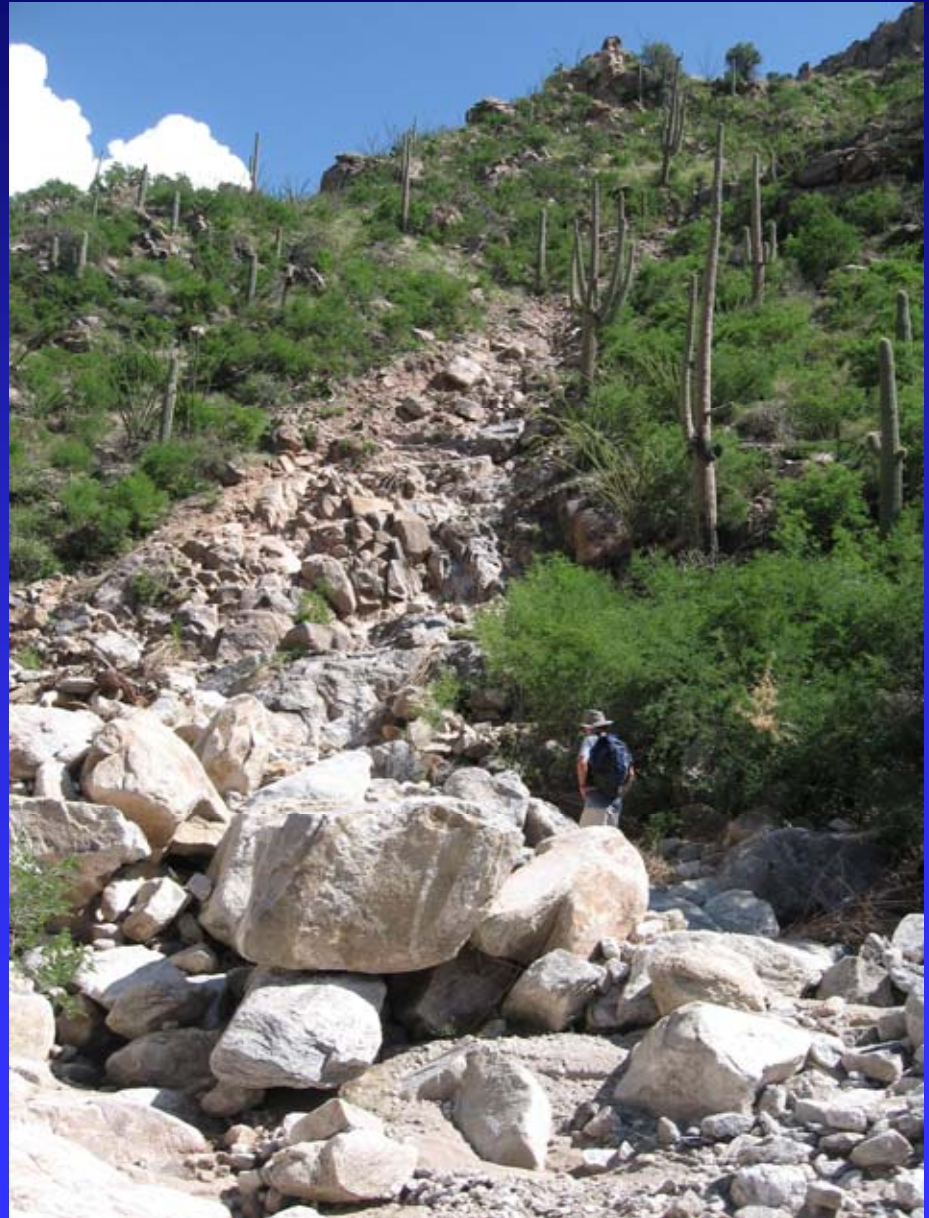


Debris-Flow History of the Santa Catalina Mountains: Little Known

- Before 2006, about five debris flows (all small) are known to have occurred in the Santa Catalina Mountains.
- In 2003, a small debris flow occurred near Tram Stop 9 in Sabino Canyon.
- A small debris flow occurred in a burned area following the 2002 Bullock Fire.
- In 1997, a small debris flow occurred in Rose Canyon.
- In 1993, another small debris flow occurred in Ventana Canyon.
- In 1983, several slope failures mobilized into debris flows in Bear Canyon.
- Depositional evidence south of the mountain front indicates a long (but perhaps dormant?) occurrence of debris flows.

What is a Debris Flow?

- A **slurry** of sediment (70-90%) and water (10-30% by weight).
- Often initiated by the collapse of sediment on a steep slope during intense or prolonged **rainfall**.
- Sediment is typically **poorly sorted**, ranging from clay (< 0.001 mm) to very large boulders (> 1 m).
- A dense, viscous **matrix** can support very large **boulders** and transport them easily over several kilometers.
- A debris flows can deposit **levees** of sediment on either side of the flow, keeping the flow channelized and maintaining forward momentum, even over open ground.

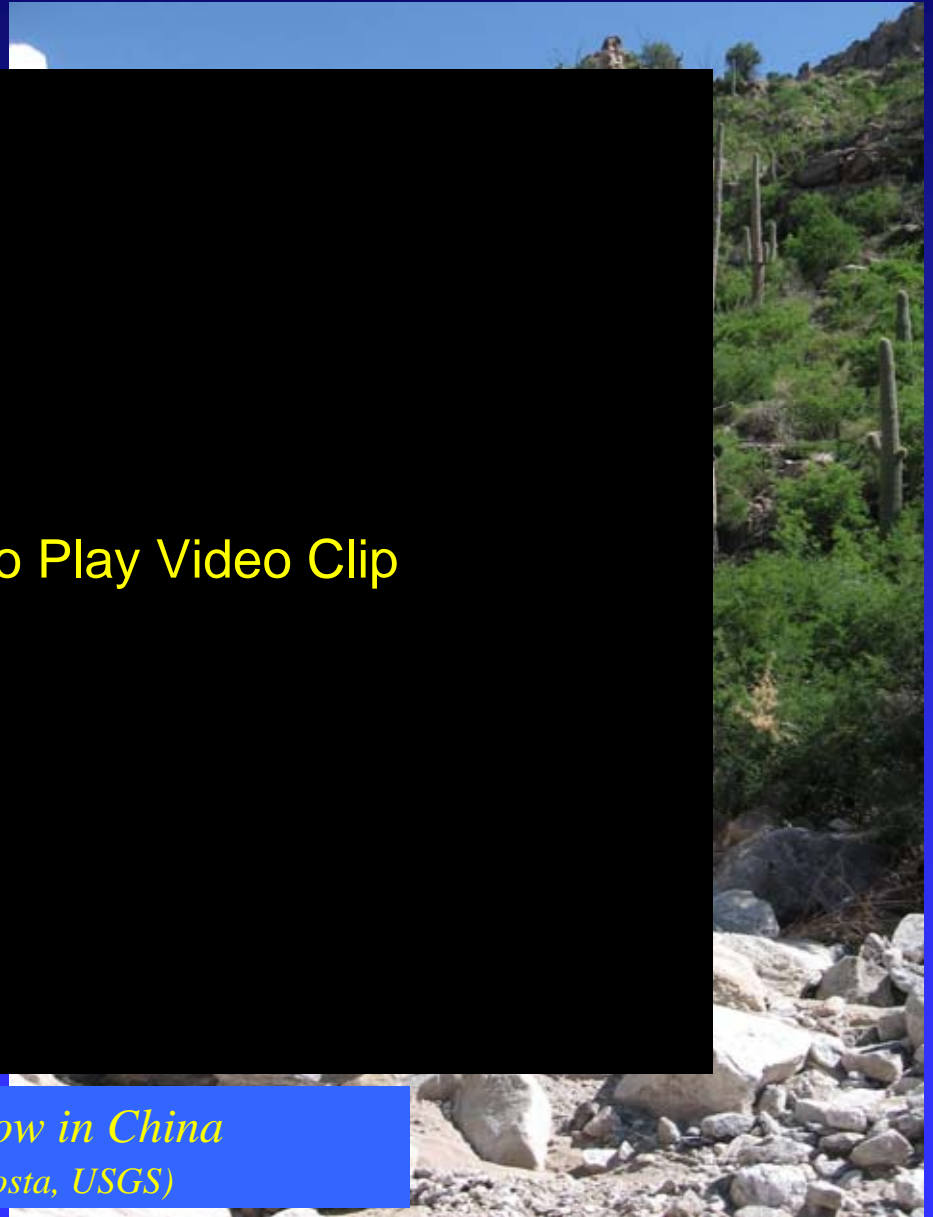


What is a Debris Flow?

- A **slurry** of sediment (70-90%) and water (10-30%)
- Often initiated by the failure of loose sediment on steep slopes during intense or prolonged rainfall
- Sediment is **poorly sorted**, ranging from fine sand (0.075 mm) to very coarse boulders (up to 100 mm)
- A dense, viscous flow that can support very large boulders and transport them tens of kilometers.
- A debris flow can move very fast, often down steep slopes, keeping its momentum, even over ground.

[Click Here to Play Video Clip](#)

Debris flow in China
(John Costa, USGS)



What is a Debris Flow?

Some debris flows only travel short distances and have large particles.



[Click Here to Play Video Clip](#)

Debris flow in Colorado
(Sue Cannon, USGS)

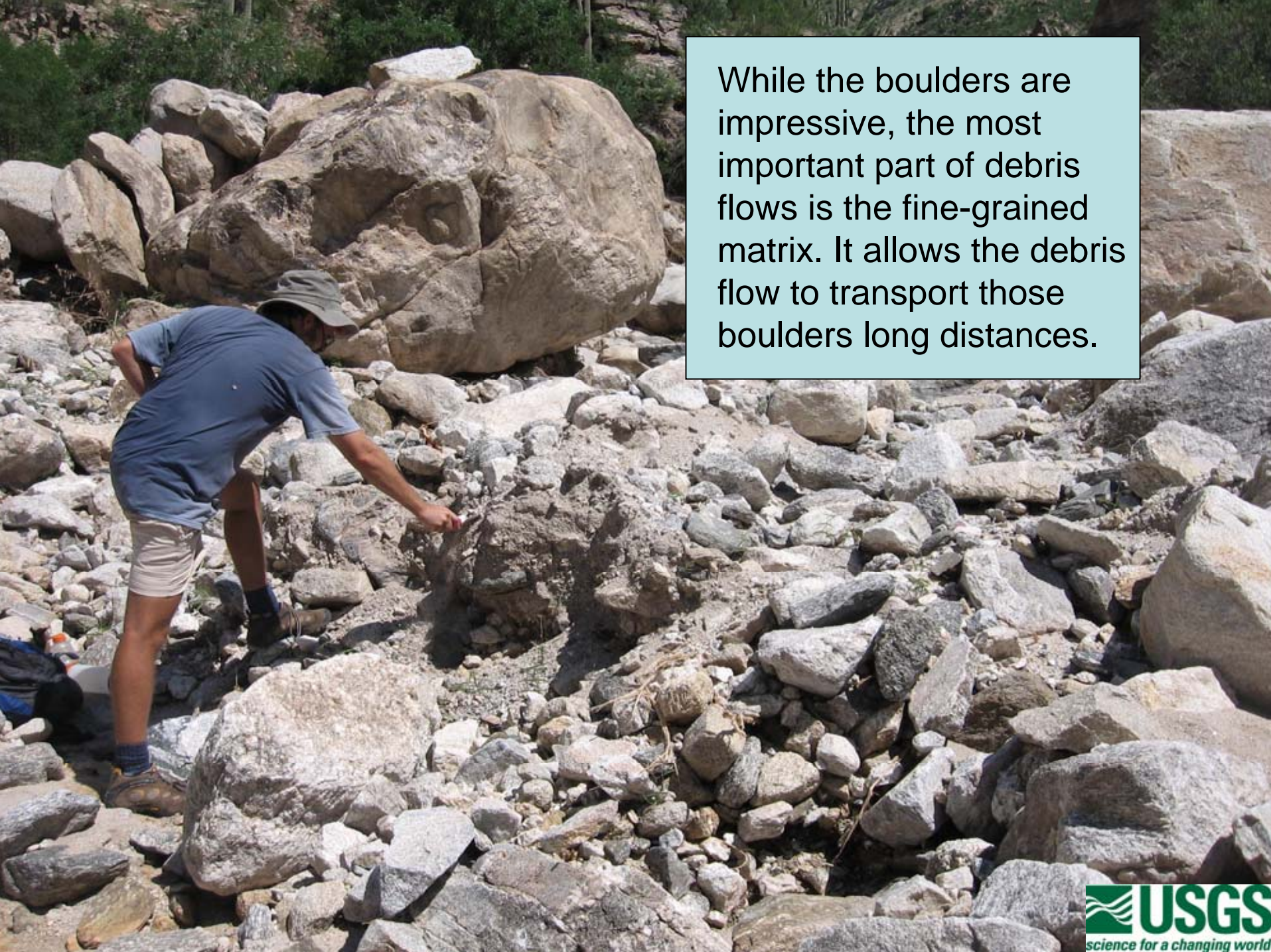
What is a Debris Flow?

Other debris flows can travel relatively long distances on low slopes.

[Click Here to Play Video Clip](#)

Debris flow in southern California
(Sue Cannon, USGS)





While the boulders are impressive, the most important part of debris flows is the fine-grained matrix. It allows the debris flow to transport those boulders long distances.

Mt. Lemmon



CATALINA MOUNTAINS

*Rattlesnake
Canyon*

*Sabino
Canyon*

*Bear
Canyon*

*Soldier
Canyon*

N Sabino Canyon Rd

Webster St

Image © 2006 TerraMetrics

© 2006 Navteq

E Summer Trl

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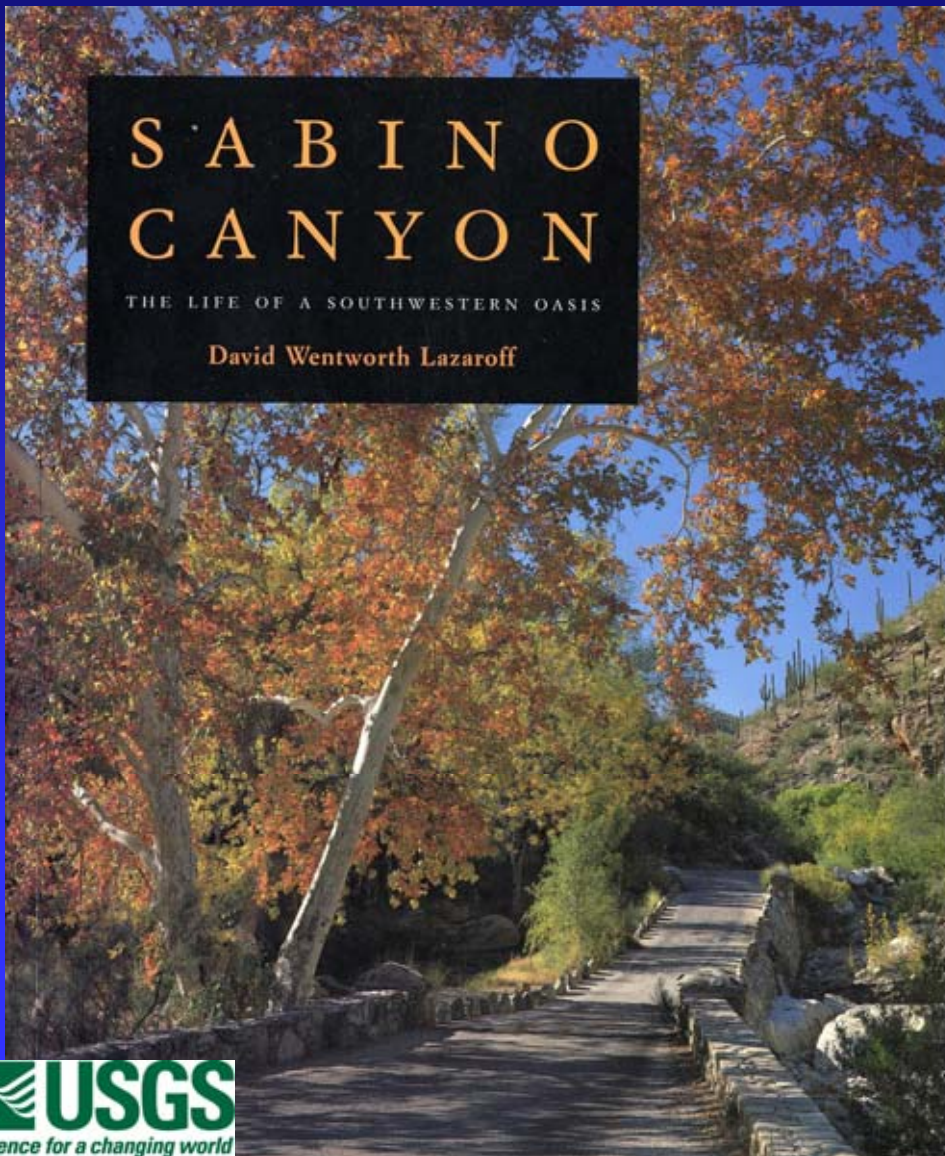


Pointer: 32°19'06.98" N 110°47'09.99" W elev 2983 ft

Streaming 100%

Eye alt: 13541 ft

Sabino Canyon: Highly Valued Recreation Area for Southern Arizona



Debris Flows in Sabino Canyon

Rattlesnake

Sabino

Bear

Repeat photo pairs

09484000



On the ground in Sabino Canyon

DF #4, #5





DF #4 slide



DF #6



DF #7





*Scour from
DF #7*



El "Ocho Grande"



*“Ocho Grande” pushed
into creek channel*



Tram Stop 8



Tram stop #9: Lots of Boulders



Bridge outlet is choked with boulders





*New rest station is
required (trash cans too)*





*“Please Stay on
Trails
Short Cutting Causes
Erosion!”*



Debris Flow #10 and Sabino Creek



- A lot of sediment entered into the mainstem of Sabino Creek.
- A process known as reworking entrained the finer sediments, washing them downstream.
- The high sediment load led to deposition far downstream in Sabino Creek.

*Sabino Canyon -
Western wall*

DF #9

DF #10

DF #16

DF #17

Ocho Grande failure



Phone Line Trail





Sabino Canyon – west wall

Rattlesnake Canyon upstream



Rattlesnake Canyon debris flow



Debris-flow levees in Rattlesnake Canyon

On the ground in Rattlesnake Canyon



Alternating debris-flow and hyperconcentrated-flow impulses



Fresh debris-flow levees were deposited onto old DF levees





Rattlesnake Canyon

Max depth of the Rattlesnake debris flow was modest...



...but the damage was significant



Sabino Canyon tram road at Rattlesnake

Flood Effects Below Rattlesnake



1994



8/18/2006



1994



8/18/2006





Above Rattlesnake: Upstream View Near Bridge 2

1901

2003





Above Rattlesnake: Upstream View Near Bridge 2

2003

2006



Above Rattlesnake: Upstream View Near Bridge 2

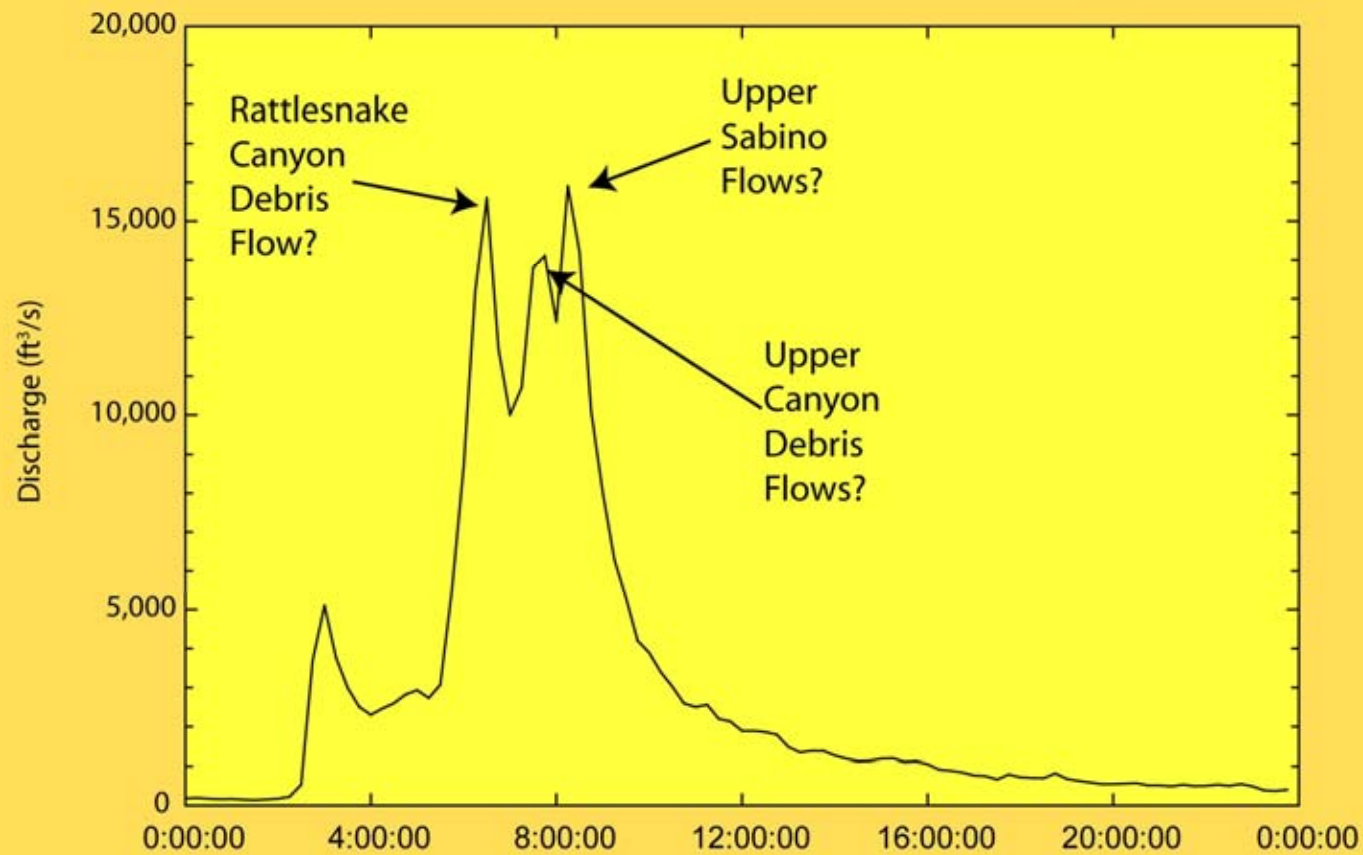


2003



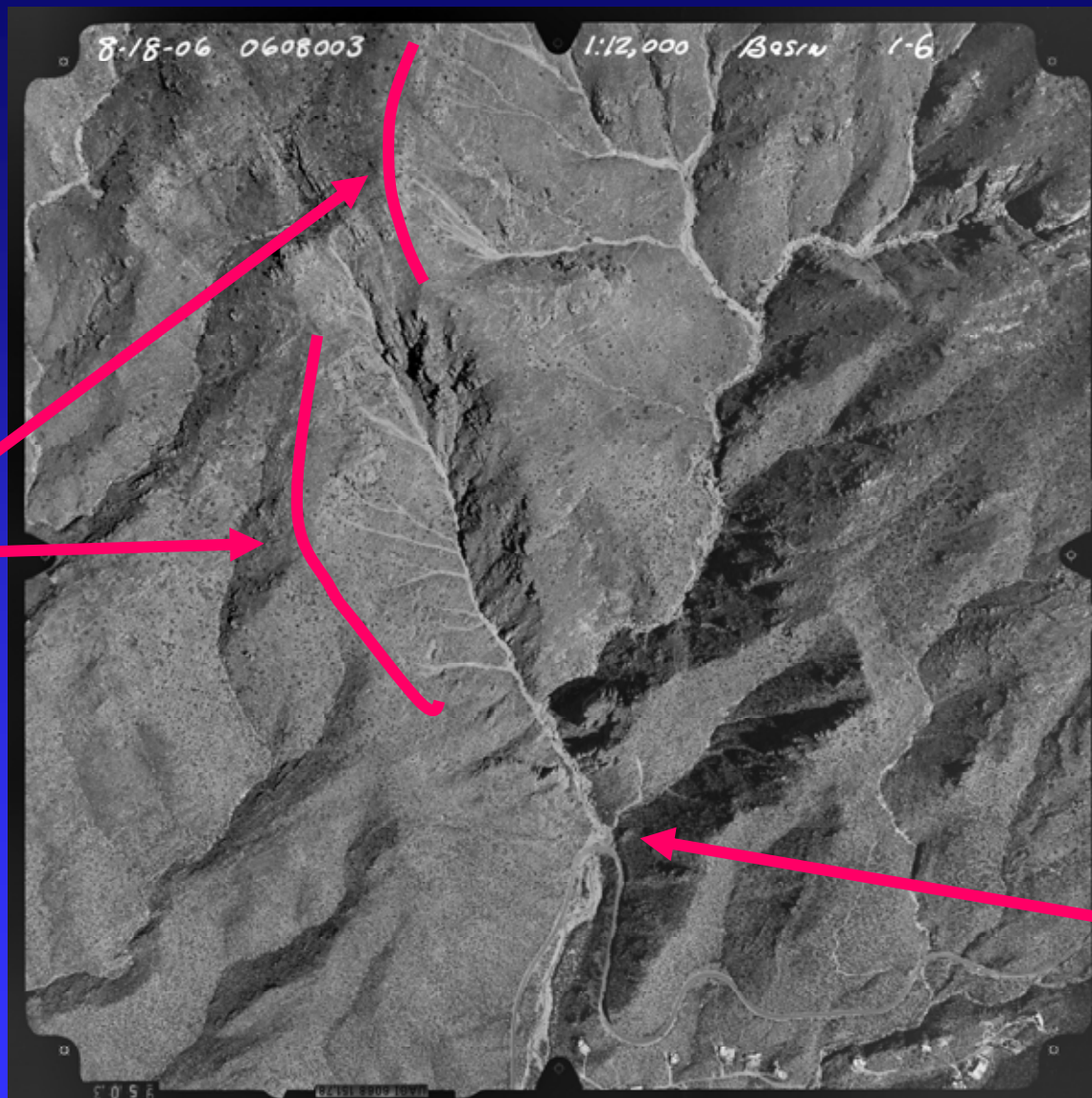
2006

Preliminary Hypothesis on Sabino Creek Hydrograph



Post-storm aerial photo of Soldier Canyon

Multiple
slope
failures
on west
side of
canyon



Infra-
structure
damage
at
Catalina
Highway
crossing

(Pima County Flood Control)



Soldier Canyon

Soldier Canyon: Debris flows and control structures



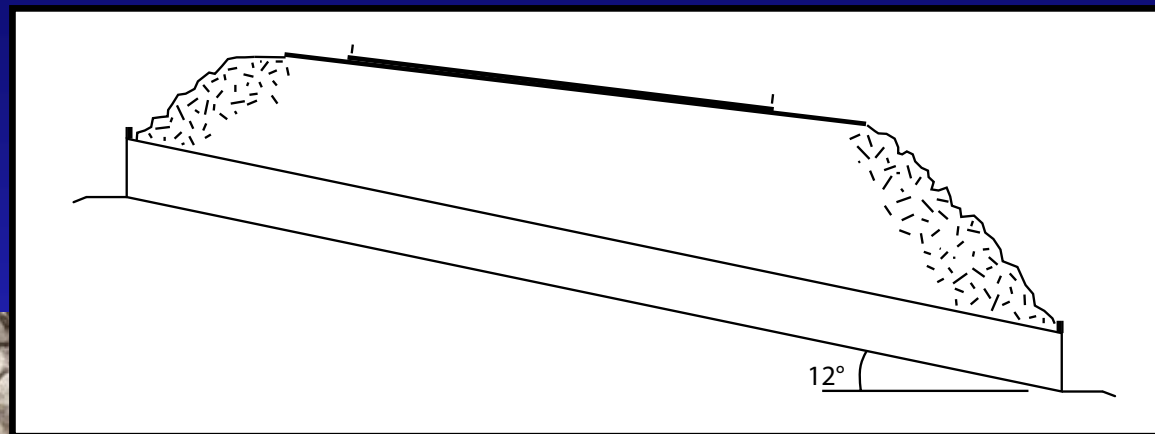
Whirlpool developed at the Catalina Highway culvert



Little deposition above culvert;
mostly erosion

Catalina Highway culvert damaged but worked beautifully

2.5 m double box culvert



- Damage to metal plated divider
- Culvert acted as a 2.5 m sieve
- Steep slope sucked DF down

Culvert at Mt. Lemmon Short Road quickly plugged with debris-flow snout



Sands, gravels, cobbles,
boulders all in matrix

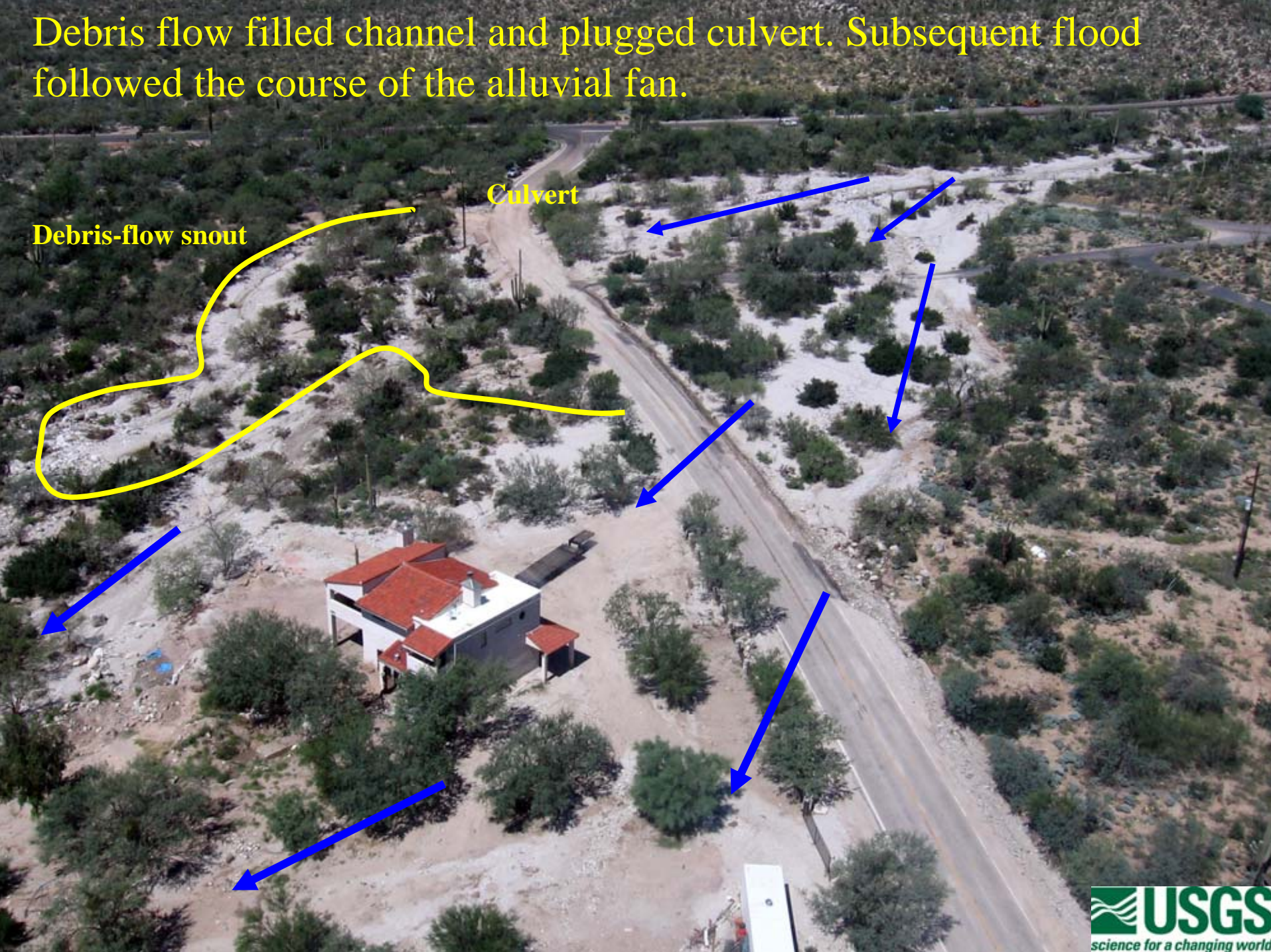


Debris-flow levee topped the guard rail

Debris flow filled channel and plugged culvert. Subsequent flood followed the course of the alluvial fan.

Debris-flow snout

Culvert



Paleo debris-flow levees near Finger Rock trail...



Paleo debris-flow levees near Finger Rock trail...

How old?



Q2 debris levee

Q3 debris levee

...at the top of Alvernon



Summary and Some Questions

- The extreme storm event of July 31 caused >240 slope failures in the Front Range of the Santa Catalina Mountains.
- Before this event, about five debris flows are known to have occurred historically in this area.
- Deposits south of the mountain front suggest a long history of debris flow occurrence, but what relevance does that have to future debris-flow hazard?
- The destabilized watersheds suggest high potential for more debris flows in the immediate future; how real is this threat?
- Debris flows greatly increased the sediment load to channels draining the Front Range of the Santa Catalina Mountains. What is the fate of that sediment? Does it increase flood hazard downstream?