TECHNICAL SERVICE CENTER
Denver, Colorado

Technical Memorandum No. 8260-95-02

Video And Thermal Infrared (FLIR) Mosaics For The Little Colorado River, Miles 13-18

Prepared by
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U.S. Department of the Interior
Bureau of Reclamation

March 1, 1995

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RES-1.10
March 1, 1995

MEMORANDUM

To: Dave Wegner, Acting, Group Manager, Glen Canyon Environmental Studies

From: Edmond W. Holroyd, III
Research Physical Scientist

Subject: Video and thermal infrared (FLIR) mosaics for the Little Colorado River, miles 13 to 18

This is a companion memorandum to a memorandum dated 19 September 1994, "Subject: LCR video mosaic" and Technical Memorandum No. 8260-95-01 (hereafter 95-01). They presented mosaics of video images, of FLIR images, and of thermal interpretations for the Little Colorado River (LCR) from the confluence with the Colorado River (mile 0) to mile 13. This memorandum extends the mosaics to nearly mile 18.

The challenge in this reach is that there are not yet any intermediate scale aerial photographs in our collection. We would have registered them to the topographic maps of the region. We would have then used landmarks (trees, rocks, shorelines, etc.) to register the video and FLIR images to the aerial photographs. Instead we had to find a way to register the latter images directly to the topographic maps. Significant errors in position have resulted.

As a general rule, there are almost no identifiable landmarks within the individual aerial video frames that are also on the topographic maps. Normal registration processes will therefore not work. It is possible to use the MIPS software to mosaic successive video frames by identifying a pair of landmarks in their overlap area. Such landmarks must be at or near the elevation of the river. Higher features have perspective errors and must be avoided. The best landmark pairs to minimize errors are those with the longest baselines. As a general rule, all video images are off-nadir, pointing forward by a variable angle as the helicopter changed the angle of attack for acceleration and deceleration. This off-nadir viewing causes the simple (point-pair) mosaics to form a series of progressively shrinking extents of the individual frames. The mosaics taper down to narrow sizes. This is clearly unacceptable.

So we have a dilemma. Individual frames cannot be registered to the topographic map. Simple mosaics with perfect nadir viewing should have sufficient landmarks for accurate registration. But the off-nadir images create mosaics with obvious distortions. In this study I made a compromise and thereby introduced significant position errors. I made 5-frame mosaics (20 seconds of flight) and registered those mosaics to the topographic maps. Then I mosaicked the short mosaics automatically into 1-minute mosaics like the former memoranda. The resulting errors are usually obvious. Every fifth frame (20-second multiple) the scene jumps in size from too small to too large. The middle frames of the small mosaics (at times of 8, 28, 48 seconds) are probably near the correct scale. The size jumps are like mid-course corrections in interplanetary travel. I have intentionally left the errors in the mosaics so that future analysts will not place excessive trust in the results. Positional errors of up to 30 meters are therefore obvious. The enclosed mosaics of the red part of the video image are otherwise in the same format as in the first memorandum. The individual video frames were subsequently registered to their resulting positions in the mosaics using various landmarks. They therefore acquired the same errors as are obvious in the mosaics. (This is in the opposite order of the first memorandum, in which the individual frame registrations were made first from an intermediate

orthophotoquad and then the mosaics were made.)

The resulting 1-minute mosaics from about mile 13 to 18 of the LCR are useful in showing the detail near the river which is not available on the topographic maps. They can serve as a substitute for orthophotos (at 0.8 m resolution) until a better image set is available.

The FLIR images were filtered as before (as in 95-01) to remove the line pairing. They were individually registered to the individual video frames taken at about the same time. The frames thereby acquired the same position errors as are in the video mosaics. Where the frames, captured at 4-second intervals, did not overlap, intermediate frames were captured at times offset by 2 seconds. No tendency was observed whereby the intermediate captures had brightness offsets as were observed between LCR miles 0 and 1. Even so, the intermediate FLIR frames were placed in the background during the mosaic process. The 1-minute FLIR mosaics are in the same format as the second memorandum.

The FLIR data were transformed into Celsius temperatures by the same equations as 95-01. Mosaics were then made at 1-minute intervals. Warm springs appear in the data and will be highlighted in a subsequent memorandum (perhaps 95-03).

The prints are not labeled with traditional figure numbers. Flight time and river mile notations are on each and are summarized in Table 1. Video mosaics are in B&W for the red component of the image and have red annotation. Direct FLIR images are in B&W, with white=warm and black=cool. Temperature interpretations of FLIR data are in color according to the scale on the image.

Table 1. Inventory of illustration identifications. For each scene there are three image types: video, FLIR, and temperature, which are identified in the annotation.

Starting minute MST:	07:53	54	55	56	57
River Mile in view:	14	14	15	16	17

As before, an ERDAS version of these mosaics is being generated for Patrick Wright for reference.

Recommendations

The significant positional errors evident in these mosaics at the "mid-course corrections" emphasize the need for nadir viewing for all mapping flights, even those for ordinary river channel imaging by the video camera on the Tyler mount. I again suggest that something as simple as a hardware store electronic level be attached to the camera to show its general attitude. Adjustments in aiming can be made when the helicopter is not changing speeds or directions.

In preparing the subsequent warm springs memorandum I made a refined mosaic for the region about river mile 14, where the off-nadir viewing was a major problem. Theoretical calculations of relative corner locations were made for off-nadir angles of 0, 5, 10, and 15 degrees. These were in an arbitrary coordinate system centered on nadir with the y-axis in the forward flight direction from an assigned altitude of 700 m above ground. These derived coordinates were forced upon each of the six video frames in the region of interest. The Plane Projective warping style in the MIPS software was used to resample the images into the proper trapezoid shape. The registration was then destroyed.

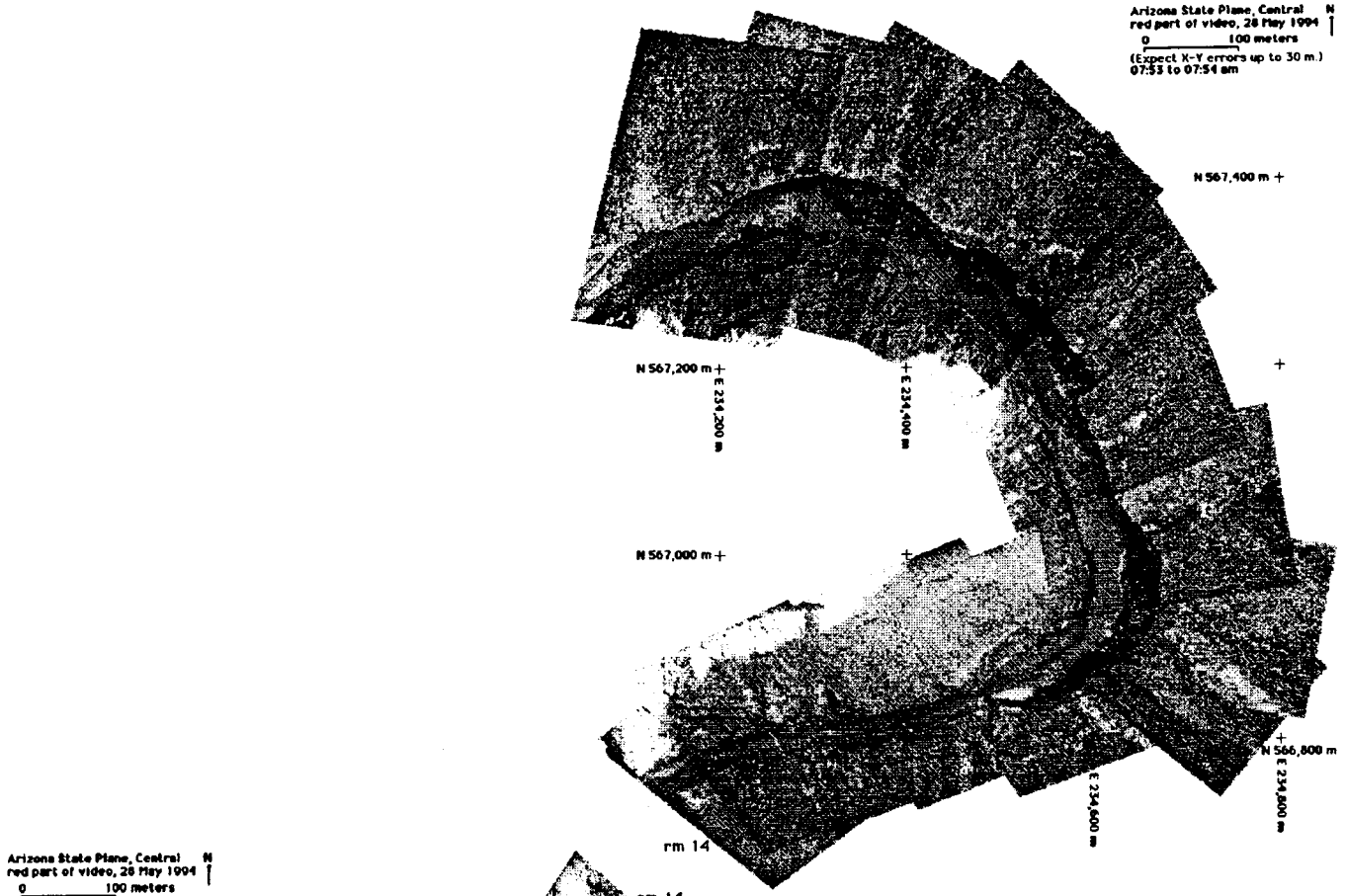
Unwarped images produced a shrinkage of the 6th image to 79% of the width of the first image in a point-pair mosaic. The warped images were also mosaicked using the point pair style. The mosaic for 10 degrees off-nadir viewing correction showed no tendency for image shrinkage. The camera was therefore

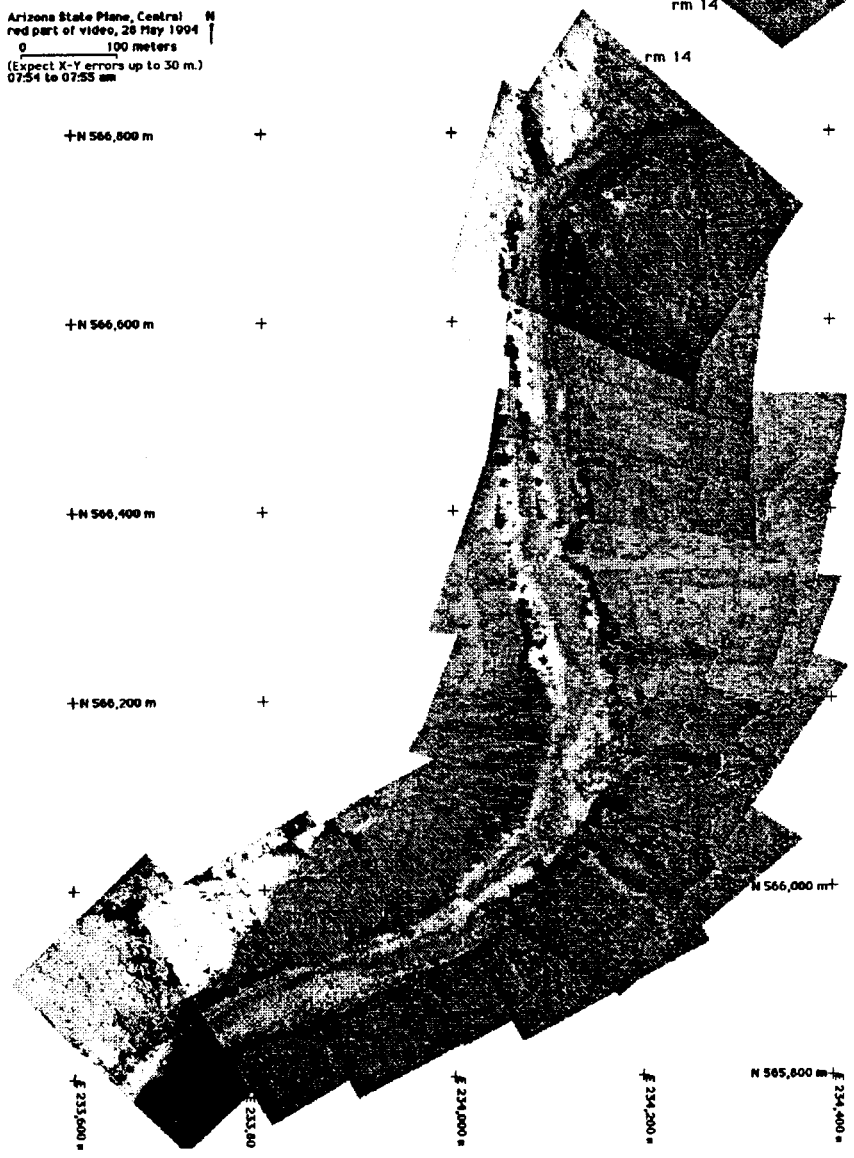
pointing 10 degrees forward of the nadir position. The resulting mosaic was then registered to the topographic map. This procedure, finding out the best off-nadir warping correction and then making the mosaic, appears to produce better results than presented in this memorandum. However, it involves numerous trials to arrive at the proper correction. Doing this procedure for the five miles in this memorandum would certainly improve the registration, but it would significantly add to the analysis time.

There is also a need for a set of quality (any film type) aerial photographs of the upper reaches of the LCR. The lower reaches also need to be done again. The flight needs to be done at the highest sun angle, such as near noon on dates near June 21. Otherwise dark shadows will obscure details in the bottom of the canyon. The aerial photographs can then be made into a properly registered orthophoto.

Attachments (video, FLIR, and temperature mosaics)

Copy: Patrick Wright


Arizona State Plane, Central
red part of video, 28 May 1994
0 100 meters
(Expect X-Y errors up to 30 m.)
07:53 to 07:54 am
N
N 567,400 m
N 567,200 m
E 234,200 m
E 234,400 m
N 567,000 m
N 566,800 m
E 234,600 m
E 234,800 m
rm 14


Arizona State Plane, Central
red part of video, 28 May 1994
0 100 meters
(Expect X-Y errors up to 30 m.)
07:54 to 07:55 am
N
rm 14
N 566,800 m
N 566,600 m
N 566,400 m
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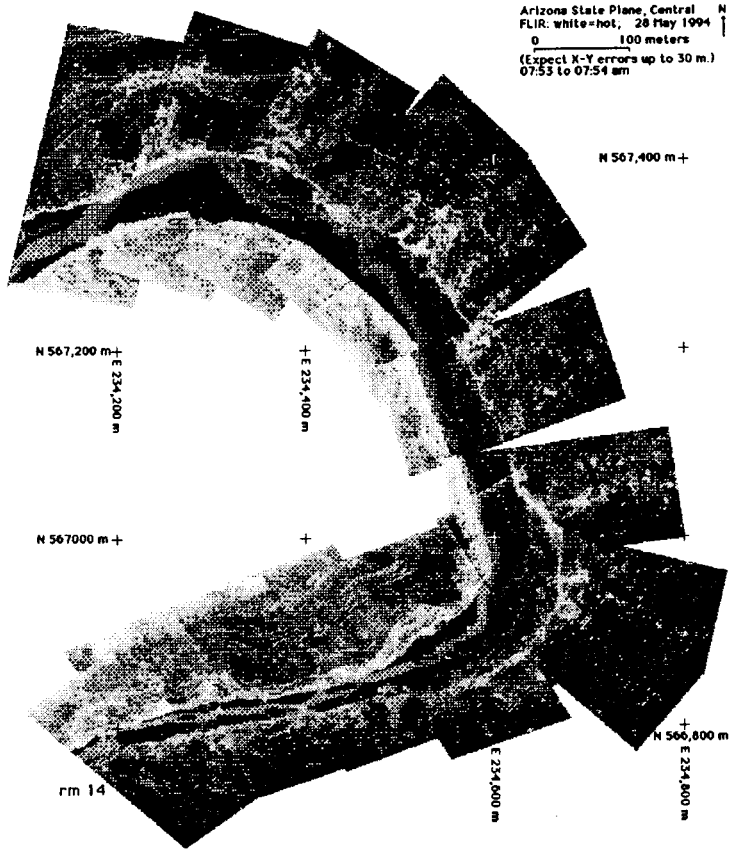
E 234,000 m
E 234,200 m
E 234,400 m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FLIR: white=hot; 28 May 1994
0 100 meters
(Expect X-Y errors up to 30 m.)
07:53 to 07:54 am
N
N 567,400 m
N 567,200 m
E 234,200 m
E 234,400 m
N 567000 m
N 566,800 m
E 234,600 m
E 234,800 m
rm 14


Arizona State Plane, Central
FLIR: white=hot; 28 May 1994
0 100 meters
(Expect X-Y errors up to 30 m.)
07:54 to 07:55 am
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N 566,800 m
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E 233,800 m
E 234,000 m
E 234,400 m
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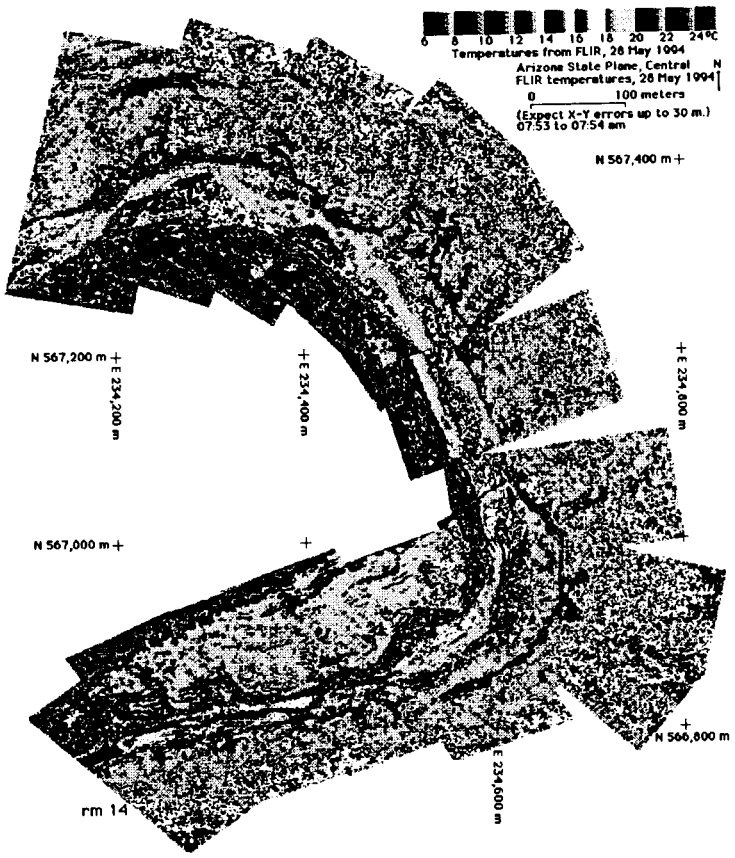
N 566,200 m
N 566,000 m
N 565,800 m
rm 14


6 8 10 12 14 16 18 20 22 24°C
Temperatures from FLIR, 28 May 1994
Arizona State Plane, Central
FLIR temperatures, 28 May 1994
0 100 meters
(Expect X-Y errors up to 30 m.)
07:53 to 07:54 am
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E 234,600 m
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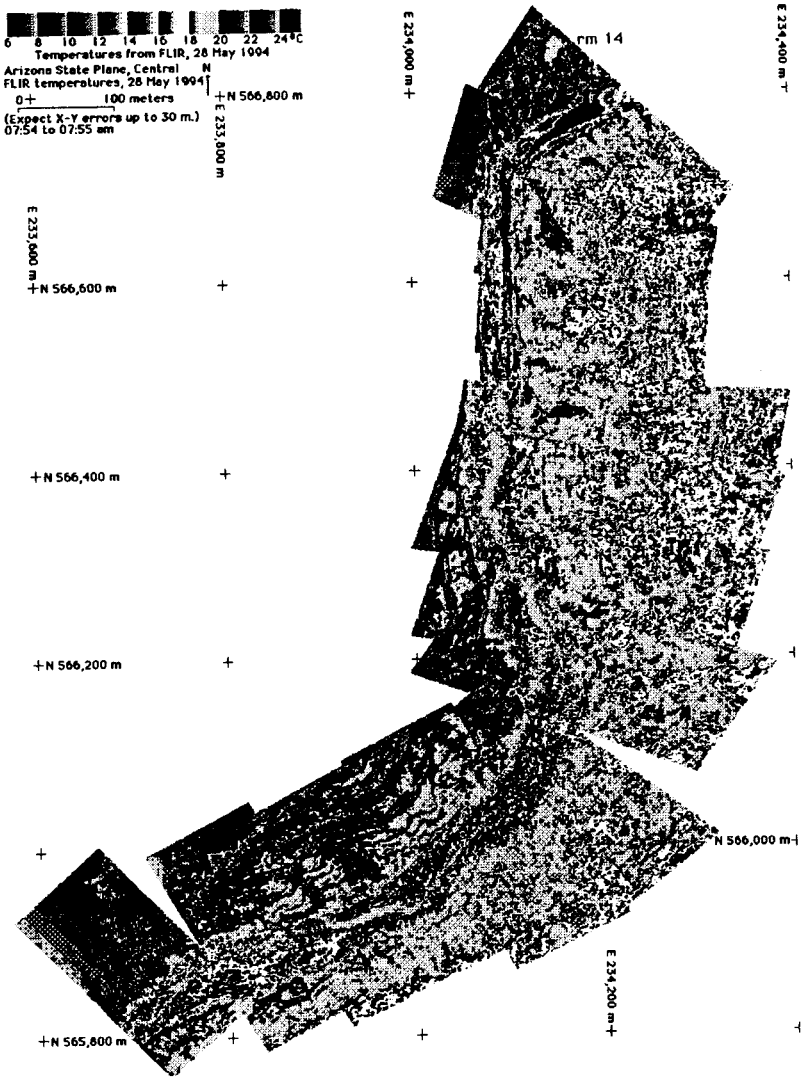
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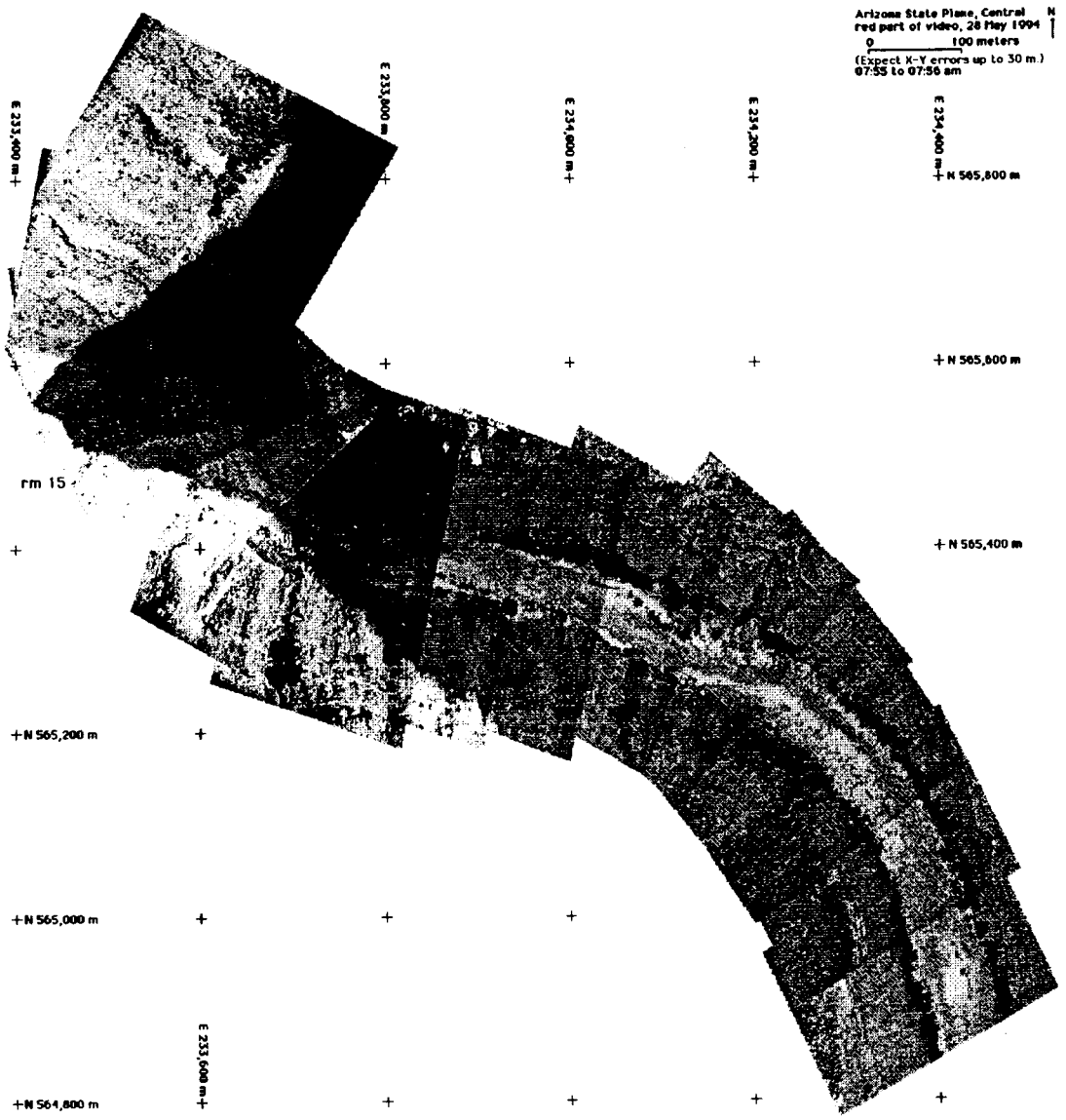
Arizona State Plane, Central
red part of video, 28 May 1994
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(Expect X-Y errors up to 30 m.)
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E 234,200 m
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N 565,800 m
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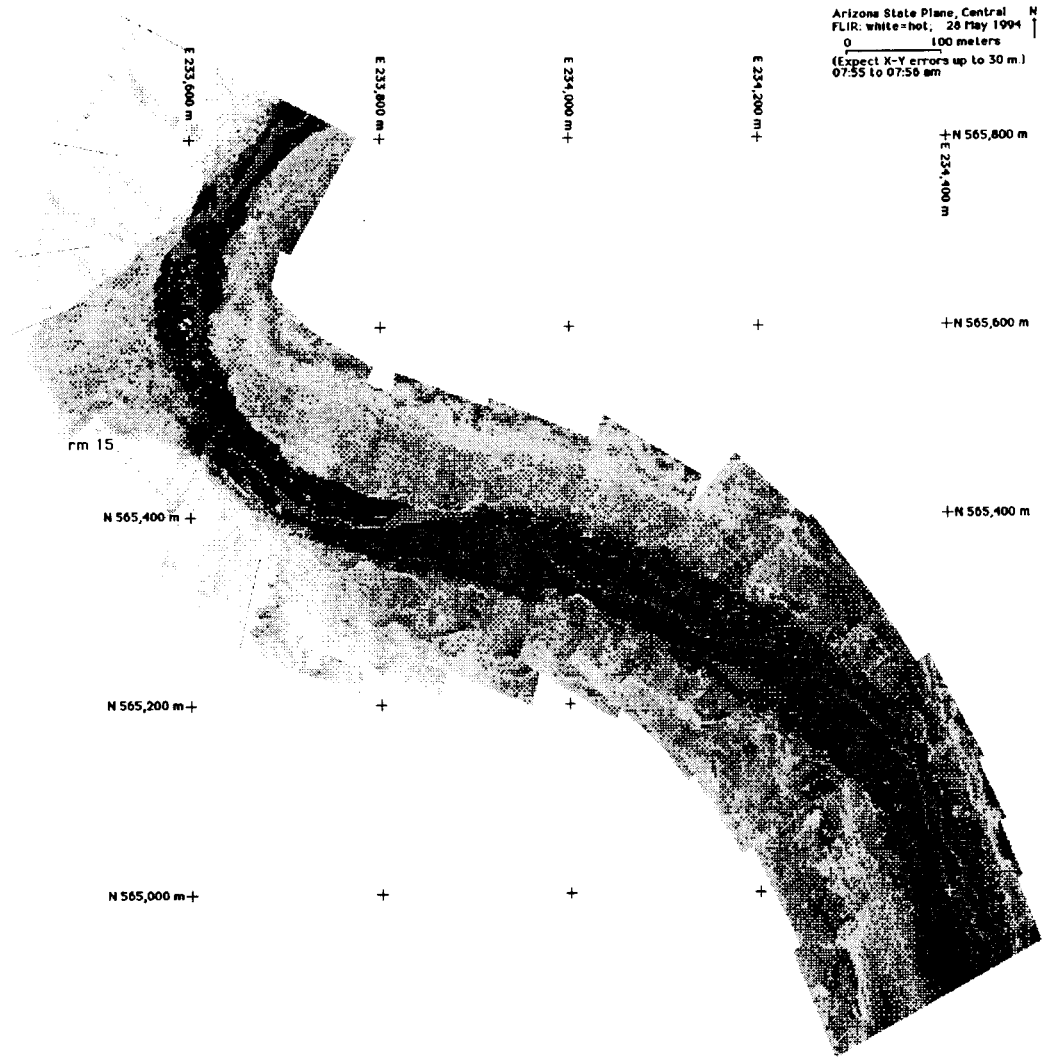
N 565,000 m
E 233,600 m
N 564,800 m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(Expect X-Y errors up to 30 m.)
07:55 to 07:58 am
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N 565,200 m
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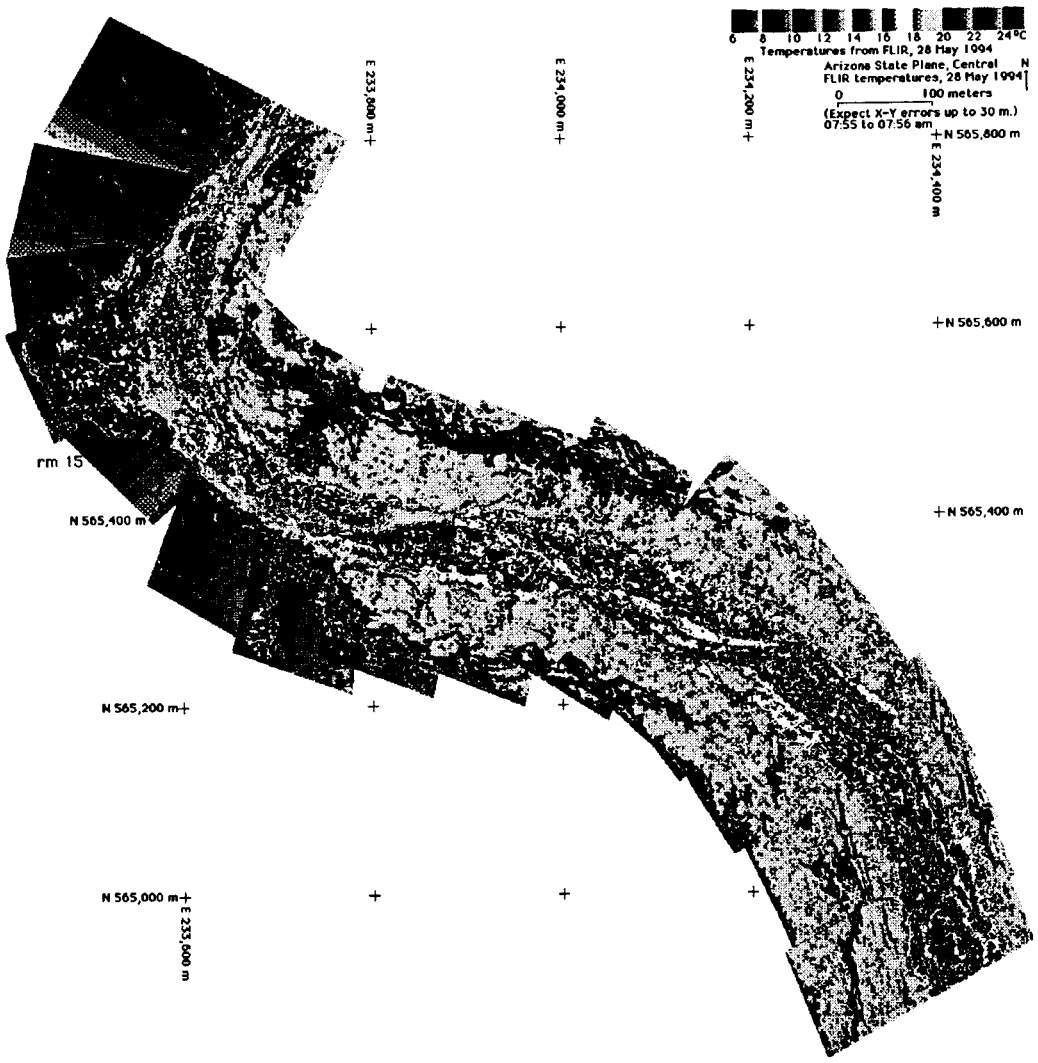
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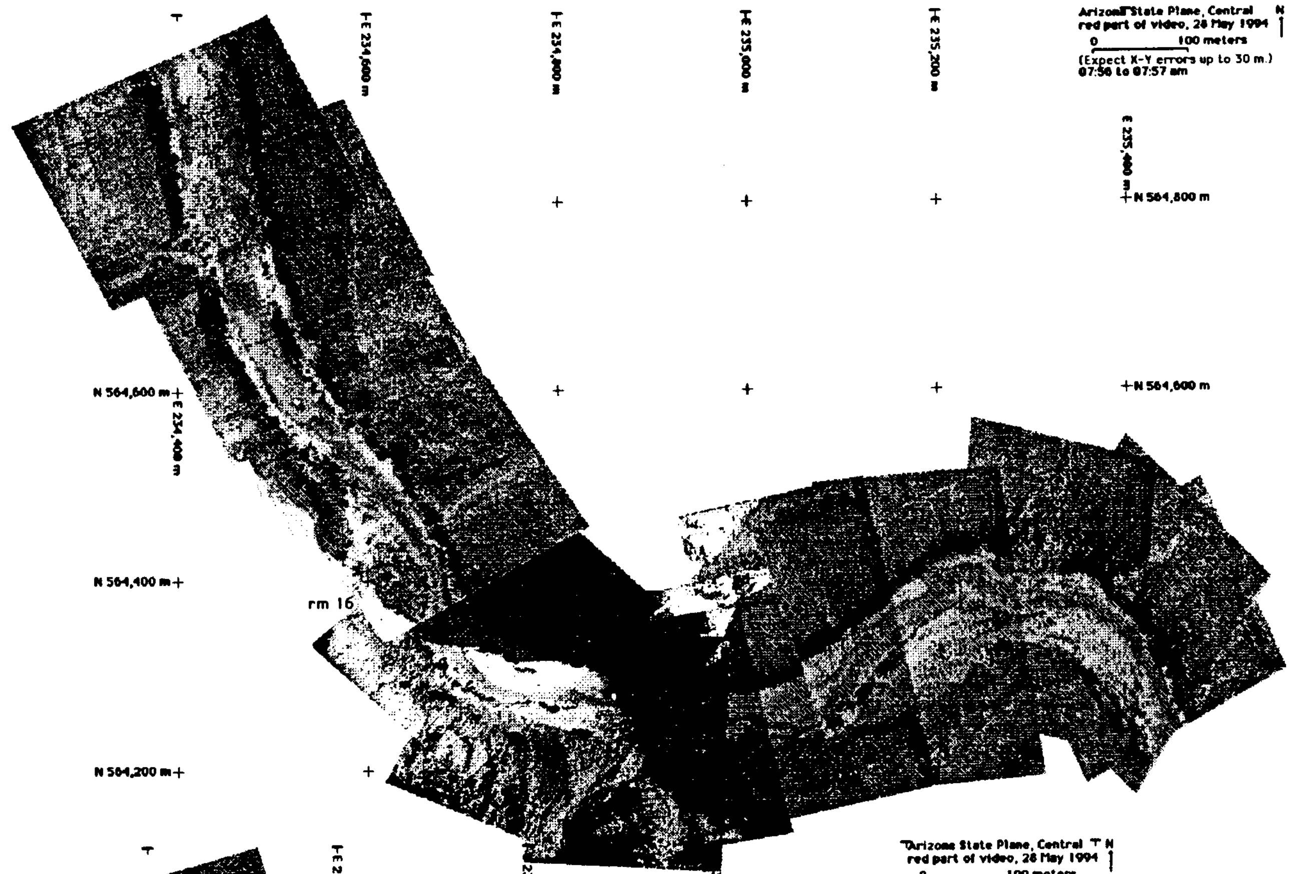
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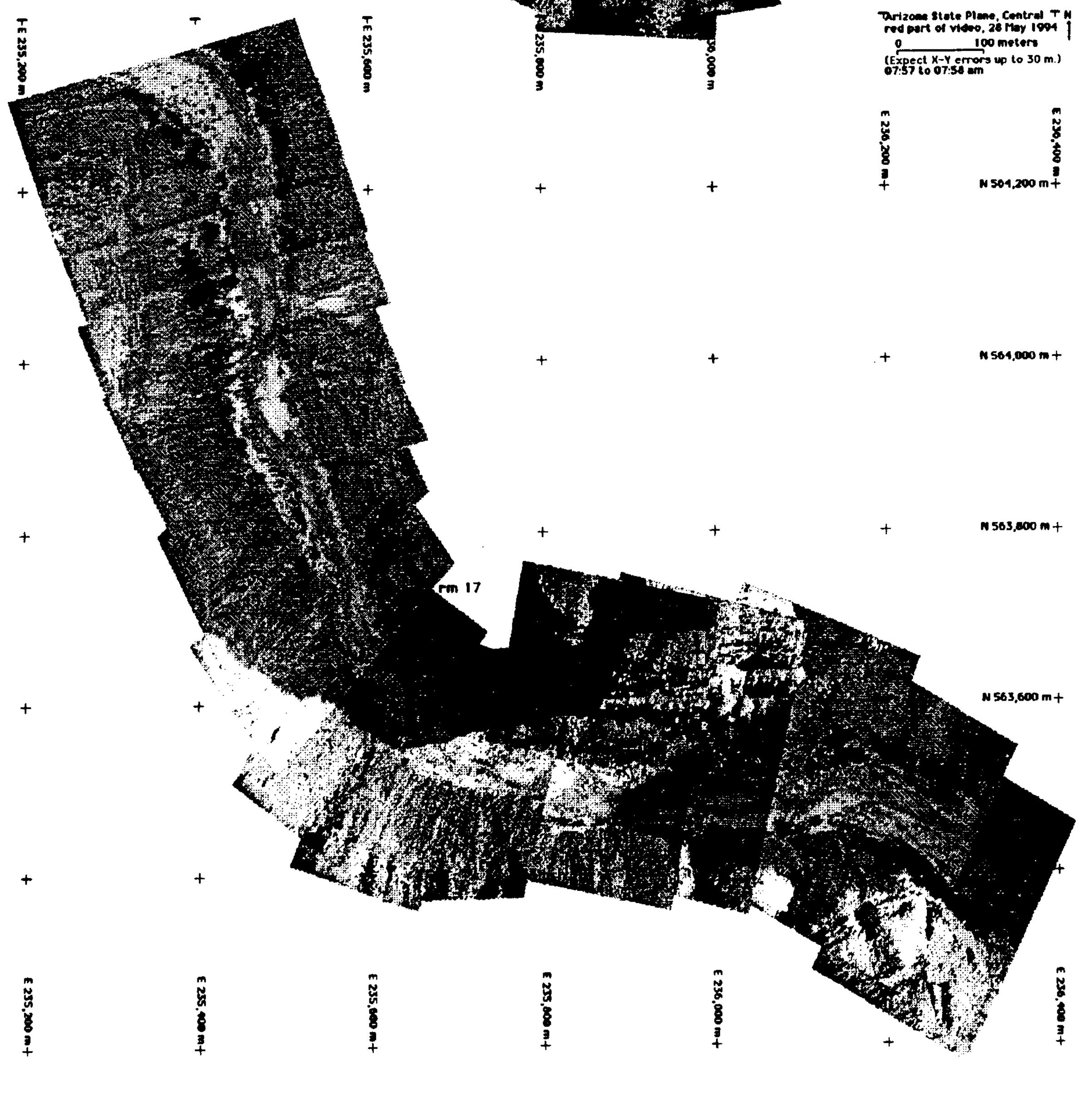
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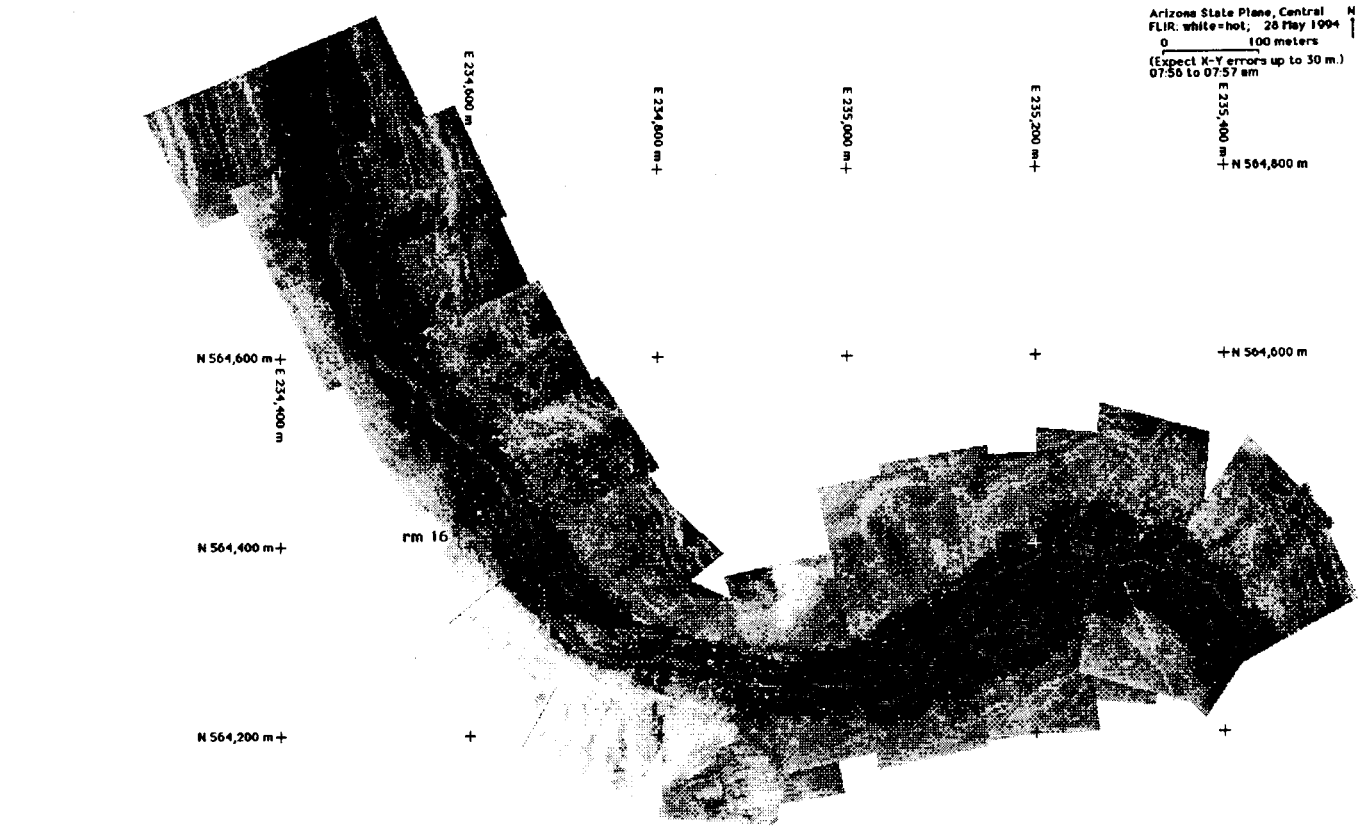
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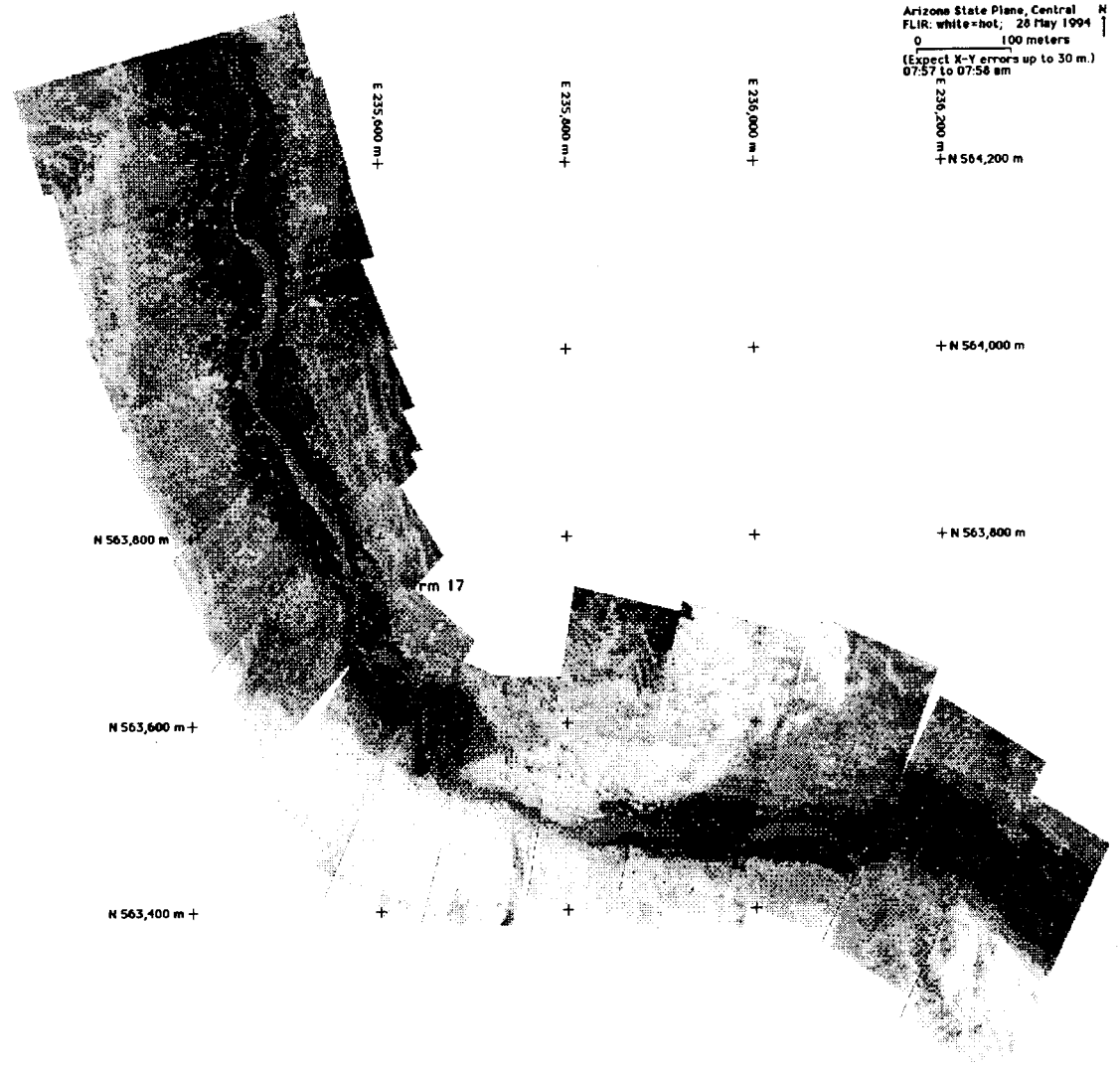
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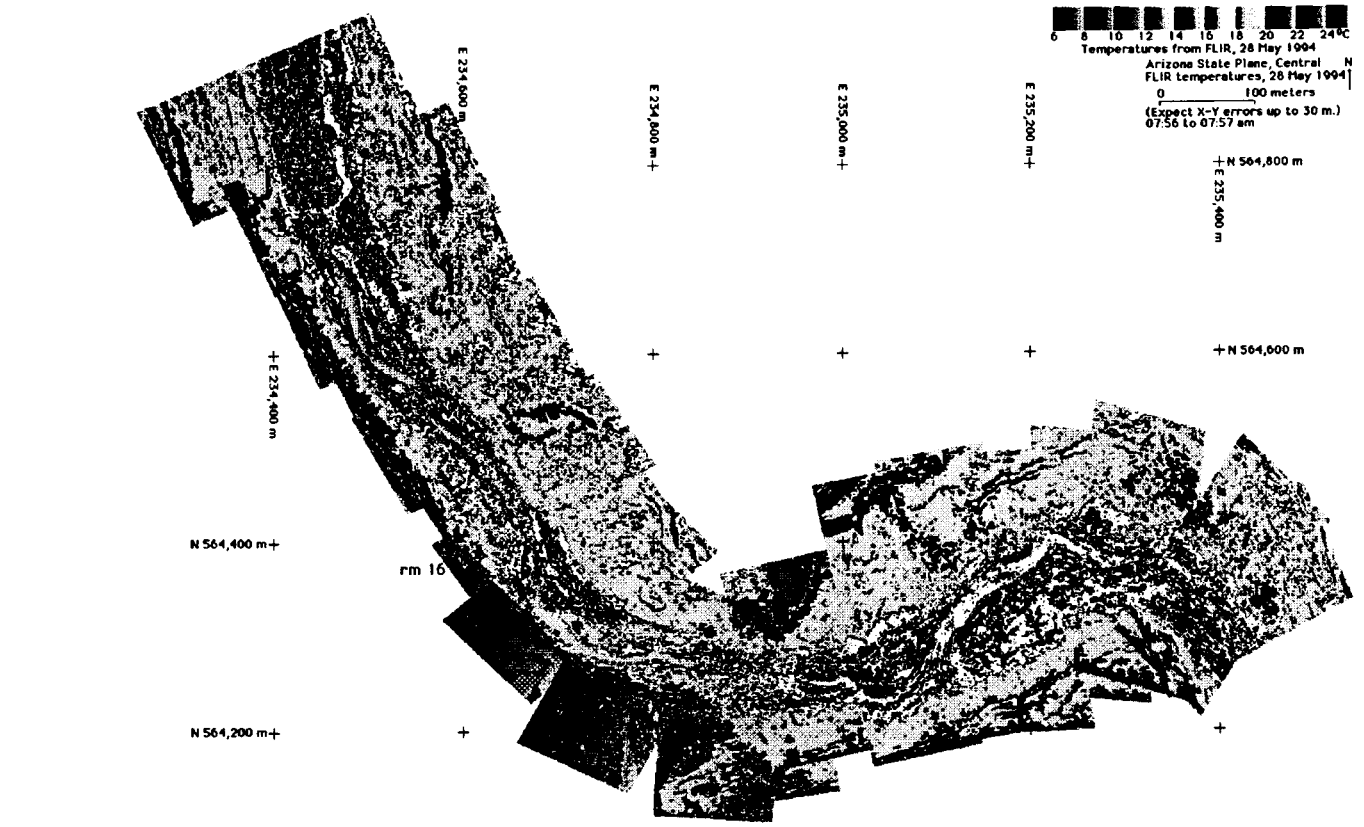
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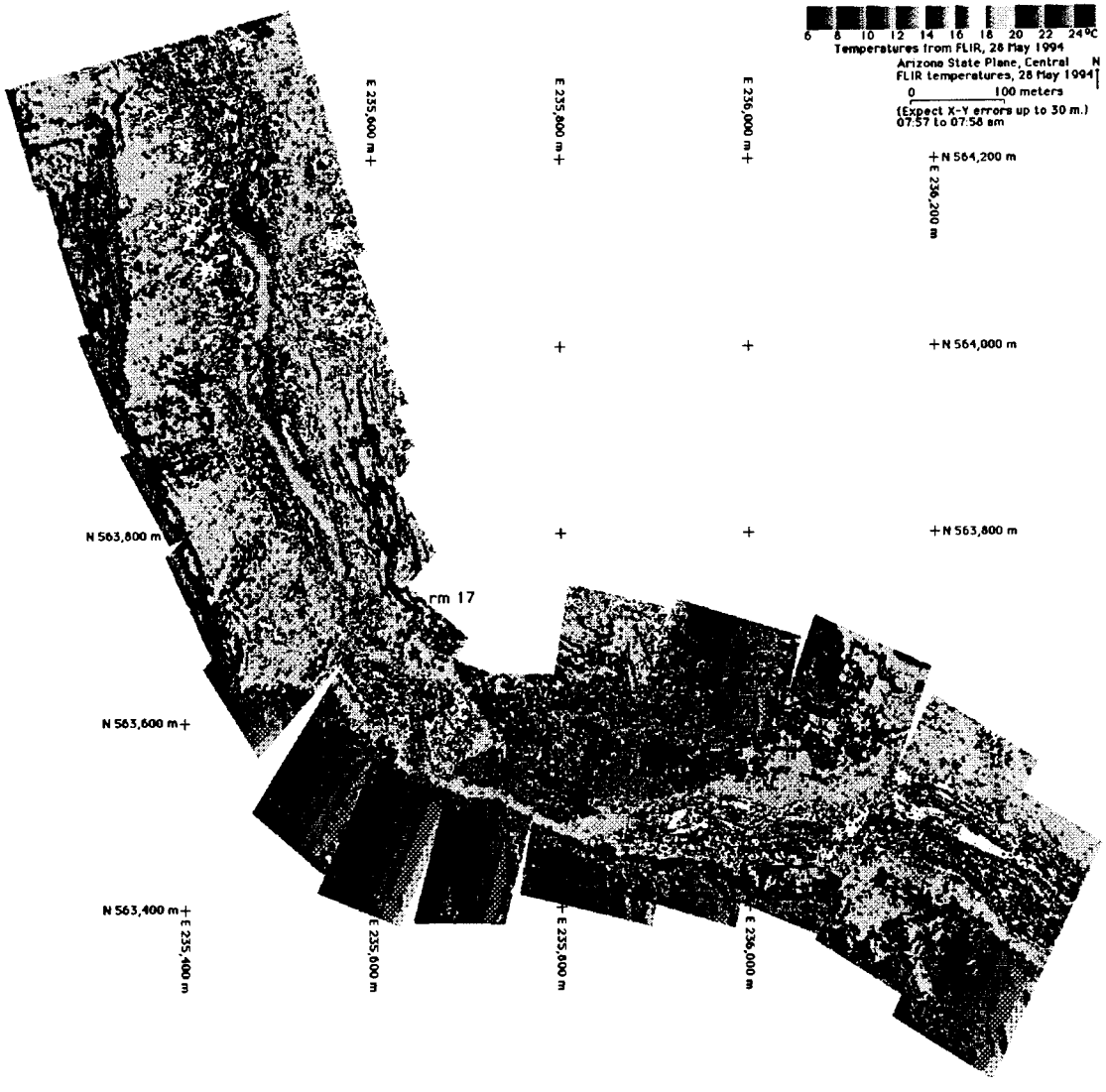
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