SESSION L

ERRORS INDUCED IN SATELLITE PHOTOGRIDS DUE TO INCORRECT INPUT INFORMATION

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Operational use of satellite photographs is made possible by the Automatic Picture Transmission System (APT) on board the meteorological satellites. The system enables the forecaster at the APT station to examine neph-cloud features in various scales that often go undetected on standard weather maps.

Proper utilization of the satellite photographs to examine these features requires the construction of an accurate latitude-longitude grid which can be superimposed on each photograph. The accuracy becomes increasingly critical as the features examined in the photograph pertain more closely to the immediate forecast problem.

Picture gridding at the APT station requires information provided about satellite positions, attitudes, and exposure time. The subsatellite latitude and longitude, and satellite height given as a function of time can, for gridding purposes, be considered correct; however, attitude information, such as image tilt (τ), azimuth of the principal line (α^{PL}), and the exposure time may contain errors which will greatly affect the accuracy of the grid.

In cases where landmarks are present, the error in picture gridding can be found by comparing the position of landmarks relative to the grid and their geographic position. In photographs in which no landmarks are present a possible picture gridding error can be found if there is a change in grid position of cloud features on two or more photographs. Since the error varies within the grid, an examination of the basic types of error permits the user to determine possible error sources and to make a reasonable correction.

The most accurate method of determining and correcting a picture gridding error is to use landmarks in the photograph which can be accurately located from a corresponding geographic map (L 1). Prominent land features such as islands, lakes, and irregularities in coast lines of land masses are identified and labeled on the photograph (L 2). Utilizing information given about satellite location and orientation, the grid (L 3) is constructed and placed on the labeled photograph (L 4). The points A through J are

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then transferred to the gridded photograph (L 4) from the geographic map (L 1) and the error, in vector form, at each point is found by connecting the transferred points with those in the photograph. It will be found that the error vectors thus obtained are, for this example, negligible over the entire grid.

In actual cases, however, the error vectors could be appreciable, making necessary an error analysis to determine the sources. Usually the errors are caused by the combination of inaccuracies in exposure time, image tilt, and azimuth. To simplify this error problem, the error due to each of these causes is discussed.

Time Error: If the grid is constructed using an incorrect exposure time and placed on the photograph (L 5), the error vector at each reference point can be determined. It will be seen that these error vectors are oriented, in this case, toward the north-east portion of the photograph. This orientation is parallel to the Satellite Subpoint Track. In order to correct the entire grid, it is necessary to either interpolate or extrapolate the error vectors at each latitude-longitude intersection. Such a correction is feasible only if visible landmarks exist within a large portion of the image. In order to show the distribution of this type of error vector, vector time errors (L 6) were obtained by superimposing the correct grid (L 3) on the grid (L 5) constructed by using an incorrect time.

Tilt Error: The second type of error is that resulting from the use of an incorrect tilt (in this case, 5 degrees too low) for picture gridding with all other parameters being correct. When the error vectors at the landmark reference points are determined on the incorrect picture grid (L 7), it will be seen that they are parallel to the Principal Line. The vector tilt error (L 8) was obtained in the same method used in obtaining the vector time error (L 6).

Azimuth Error: Errors classified as azimuth errors may be considered as follows:

I. An error caused by aligning a correct grid using an incorrect image principal line.

II. An error induced by using an incorrect azimuth of the terrestrial principal line to construct the grid.

A gridded photograph (L 9) and vector azimuth error chart (L 10) were constructed to show the error vectors expected for the first case. It should be noted that error vectors

rotate around the Image Principal Point. This type of azimuth error would be most likely found in those photographs with little or no horizon to aid in the determination of the actual image principal line.

To illustrate the second case, a gridded photograph (L 11) and the vector azimuth error (L 12) are prepared. Unlike the first case, the vector errors now rotate around the Image Subpoint.

Determination of vector errors on an image with a well-defined horizon appears on the chart (L 13). The horizon itself provides an indication of erroneous gridding if there is a tilt error or if the grid has been aligned along an incorrect image principal line (case I). If, however, the grid error is the result of using an incorrect exposure time or using an incorrect azimuth of the terrestrial principal line (case II), all other parameters being correct, no displacement of the computed horizon relative to the apparent horizon will be observed.

Conclusions:

A method of error vector determination presented in this paper is applicable to any gridded satellite photograph including visible landmarks. With the use of a reasonable number of such landmarks, a field of error vectors can be established. Such a field permits us to estimate the causes of errors by comparing the field with that computed by introducing given errors in exposure time, tilt, and azimuth. After knowing major causes of the error it is usually feasible to make proper correction to the grid.

L1

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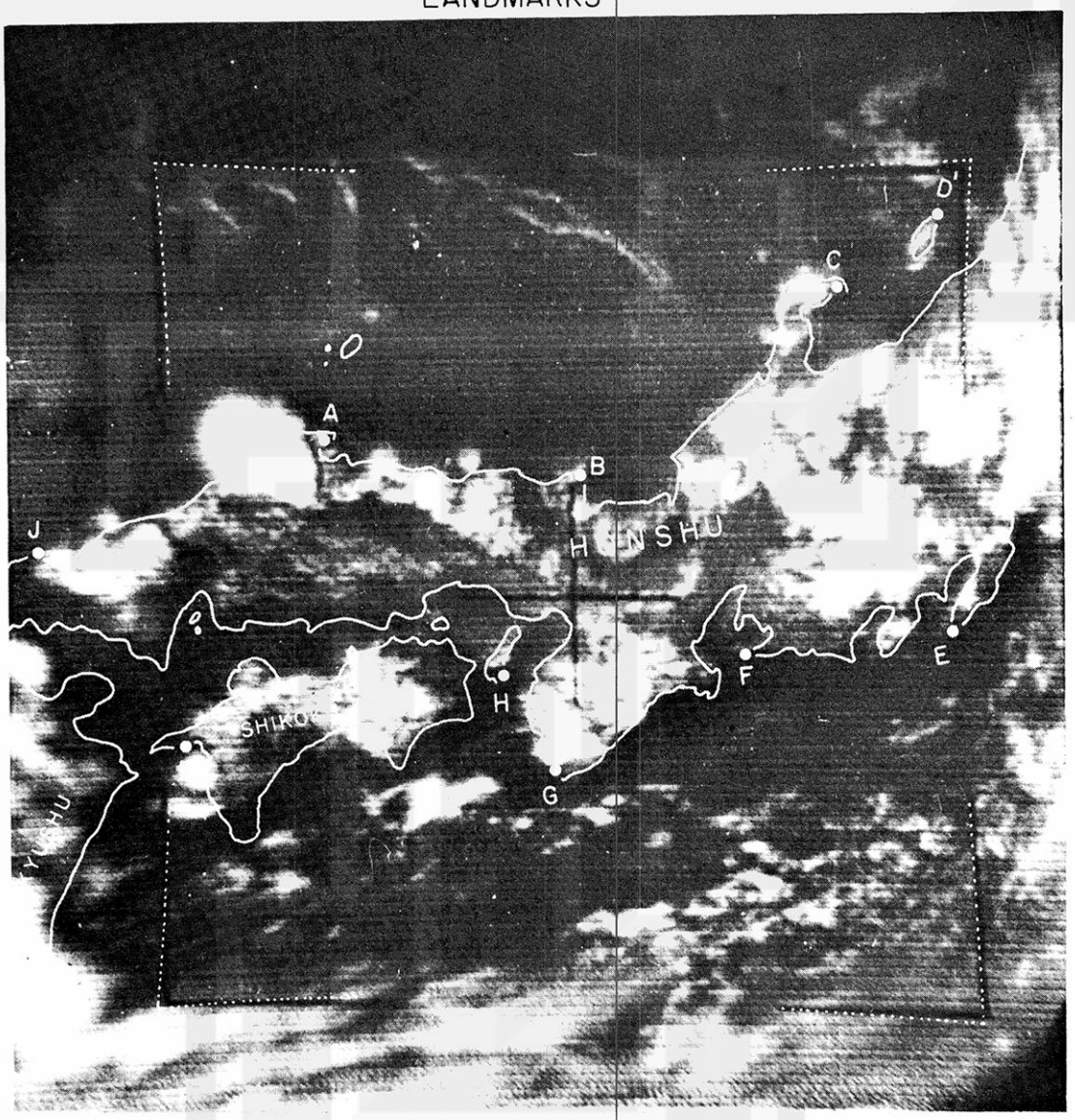
L2

CLOUD PHOTOGRAPH 0525.5 Z AUG. 5, 1963

TIROS VII A/O 692 R/O 692

TAPE CAMERA I

LANDMARKS



FRAME 8

TIME = 0525.5 Z

τ = 23.8°

ϕ^{TSP} = 36.0N

α^{PL} = 117.0°

θ^{TSP} = 132.7E

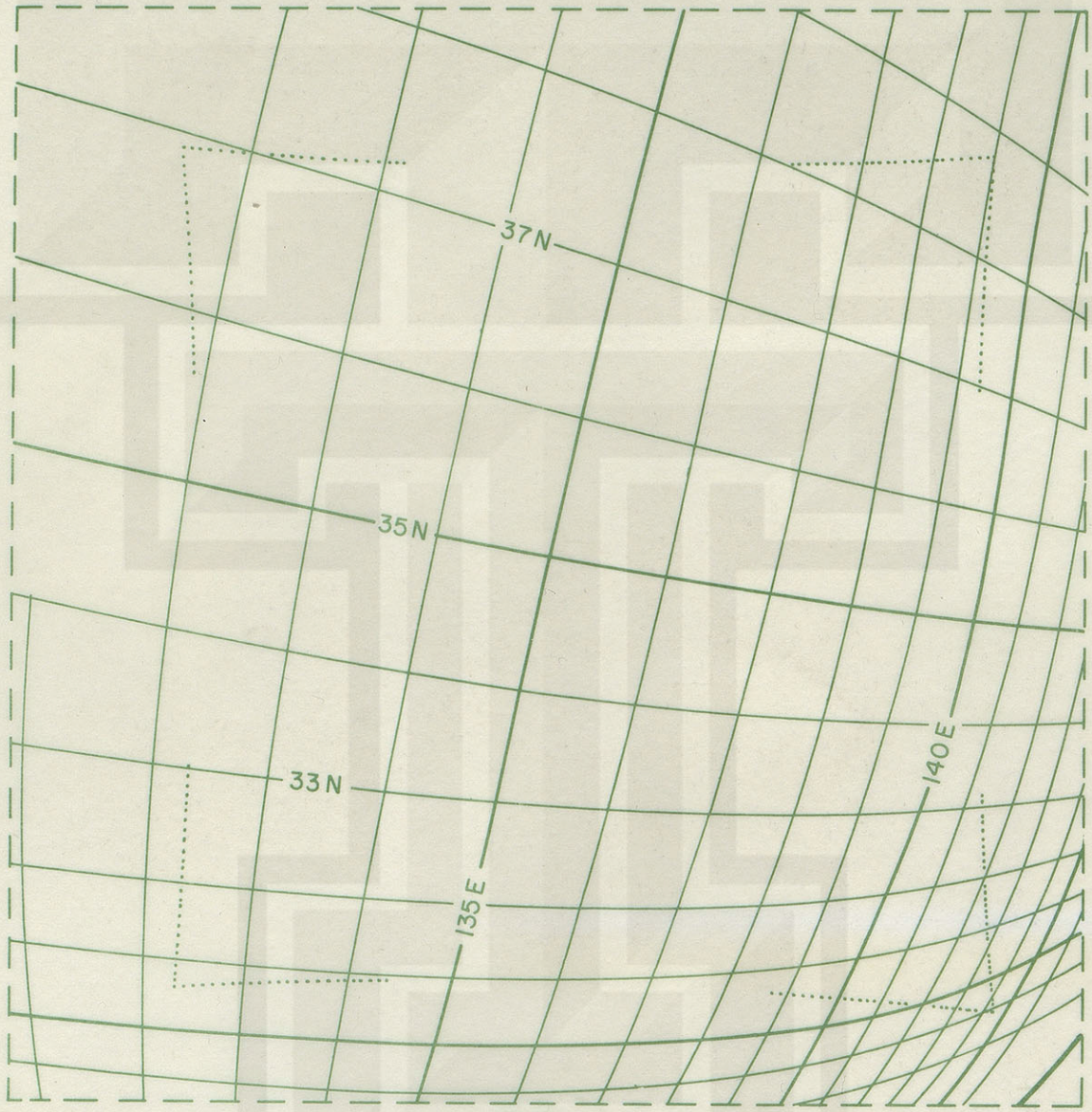
H = 627 km

L3

PICTURE GRID 0525.5 Z AUG 5, 1963

TIROS VII A/O 692 R/O 692

TAPE CAMERA-I



TAPE 8

FRAME 8

TIME = 0525.5 Z

τ = 23.8°

ϕ^{TSP} = 36.0 N

α^{PL} = 117.0°

θ^{TSP} = 132.7 E

H = 627 km

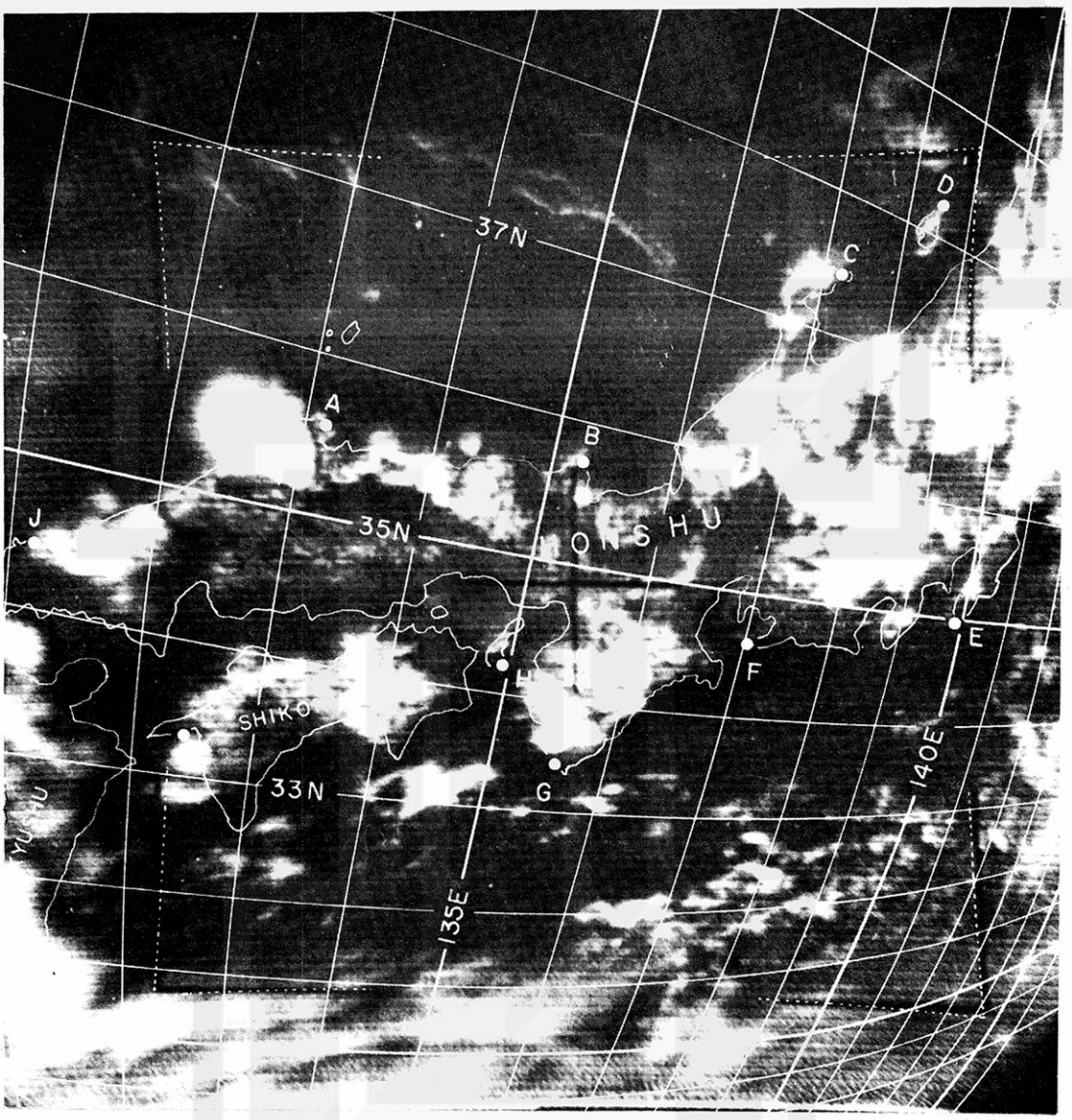
L 4

CLOUD PHOTOGRAPH 0525.5 Z AUG. 5, 1963

TIROS VII A/O 692 R/O 692

TAPE CAMERA 1

CORRECT GRID



FRAME 8

TIME = 0525.5 Z

τ = 23.8°

ϕ^{TSP} = 36.0 N

α^{PL} = 117.0°

θ^{TSP} = 132.7 E

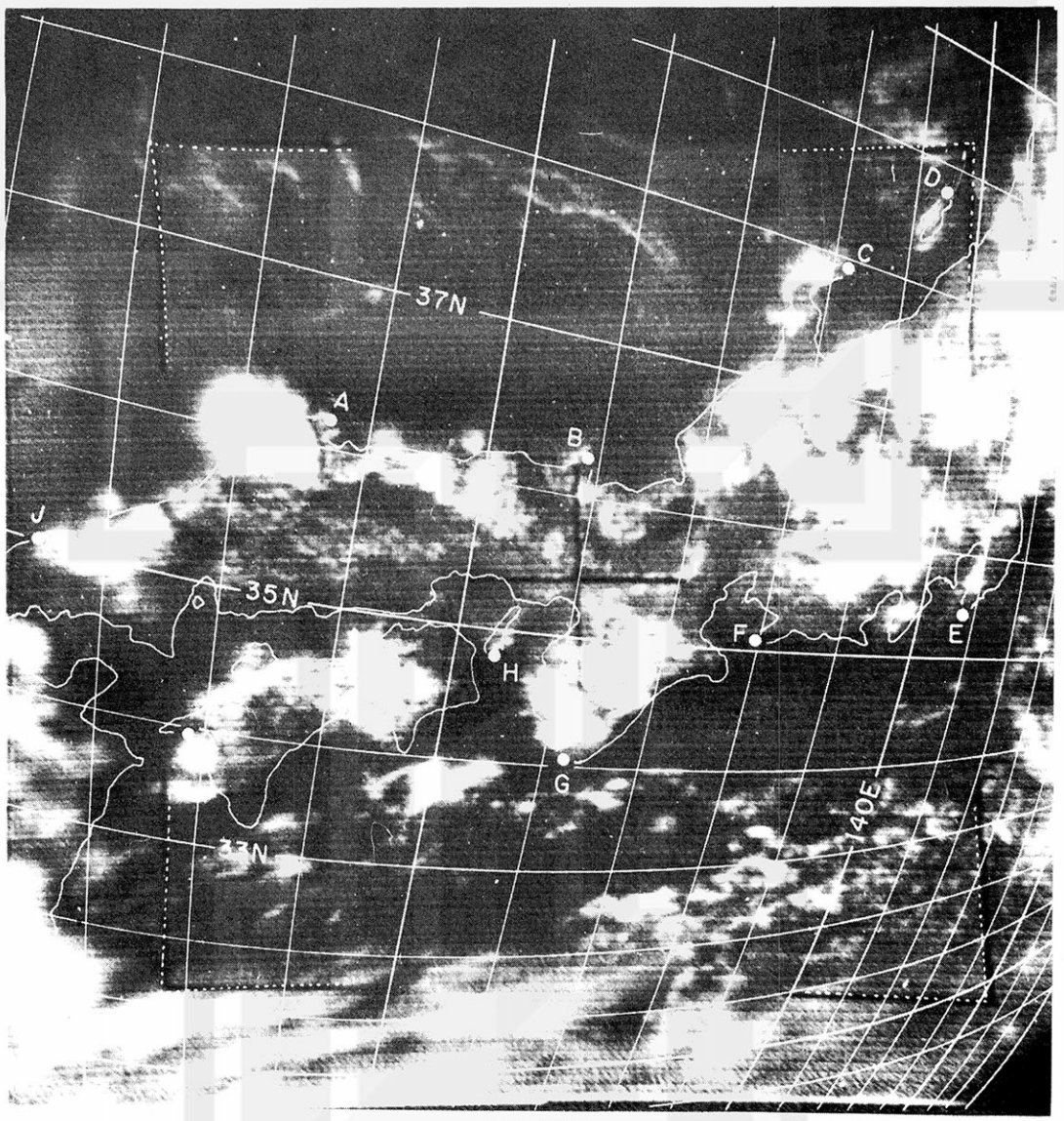
H = 627 km

CLOUD PHOTOGRAPH AUG. 5, 1963

TIROS VII A/O 692 R/O 692

TAPE CAMERA 1

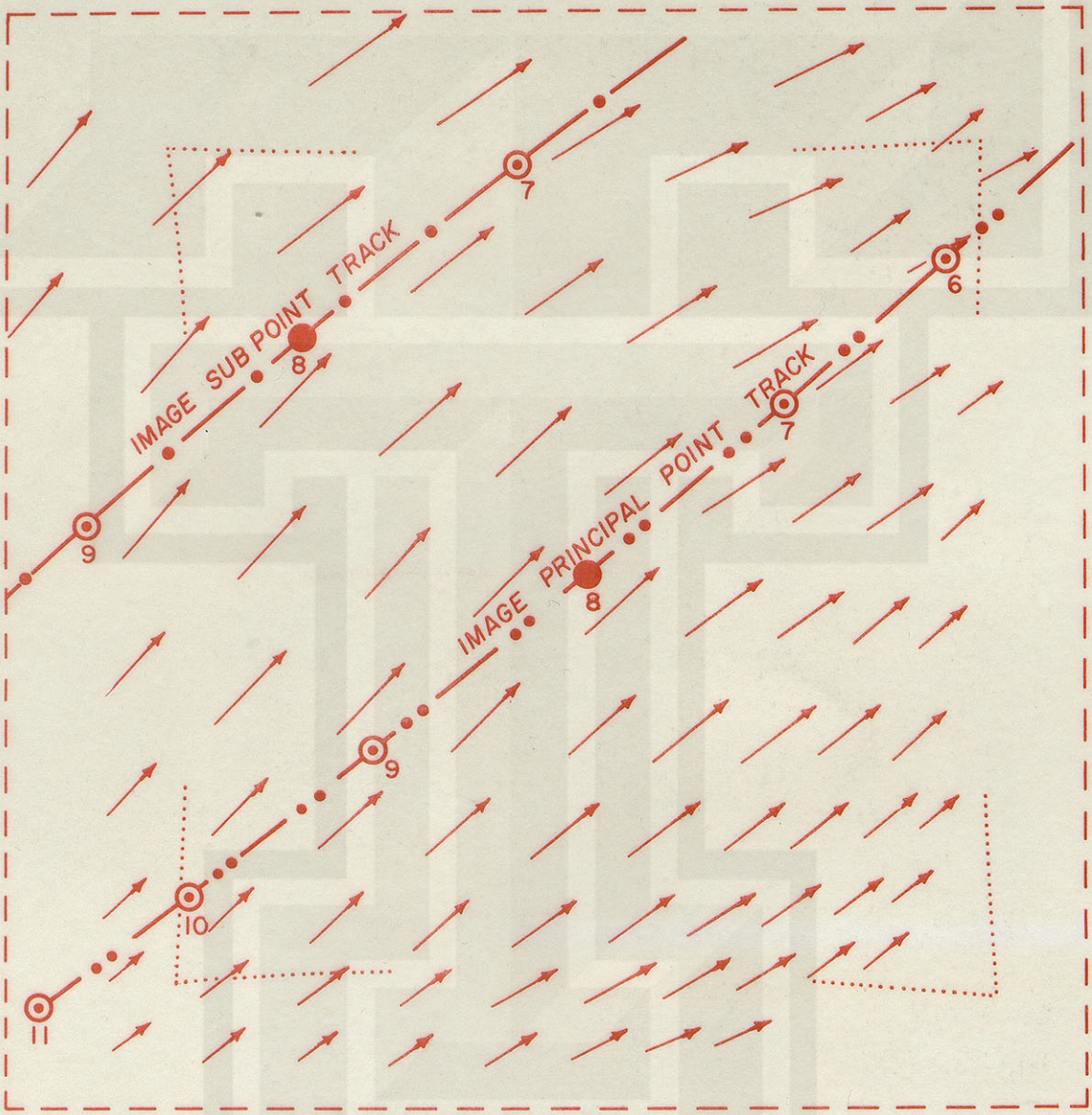
GRID TIME ERROR



FRAME 8

CORRECT		USED	
TIME = 0525.5 Z	H = 627km	**TIME = 0525.75 Z**	H = 627 km
τ = 23.8°	ϕ^{TSP} = 36.0N	τ = 23.8°	ϕ^{TSP} = 36.9N
α^{PL} = 117.0°	θ^{TSP} = 132.7E	α^{PL} = 117.0°	θ^{TSP} = 133.4E

VECTOR TIME ERROR



TAPE 8

VECTOR SHIFT REQUIRED TO ADJUST A PICTURE GRIDDING ERROR INDUCED BY USING AN INCORRECT PICTURE EXPOSURE TIME OF 15 SECONDS.

EXPOSURE TIME = 0525.5 Z
ACTUAL

EXPOSURE TIME = 0525.75 Z
USED

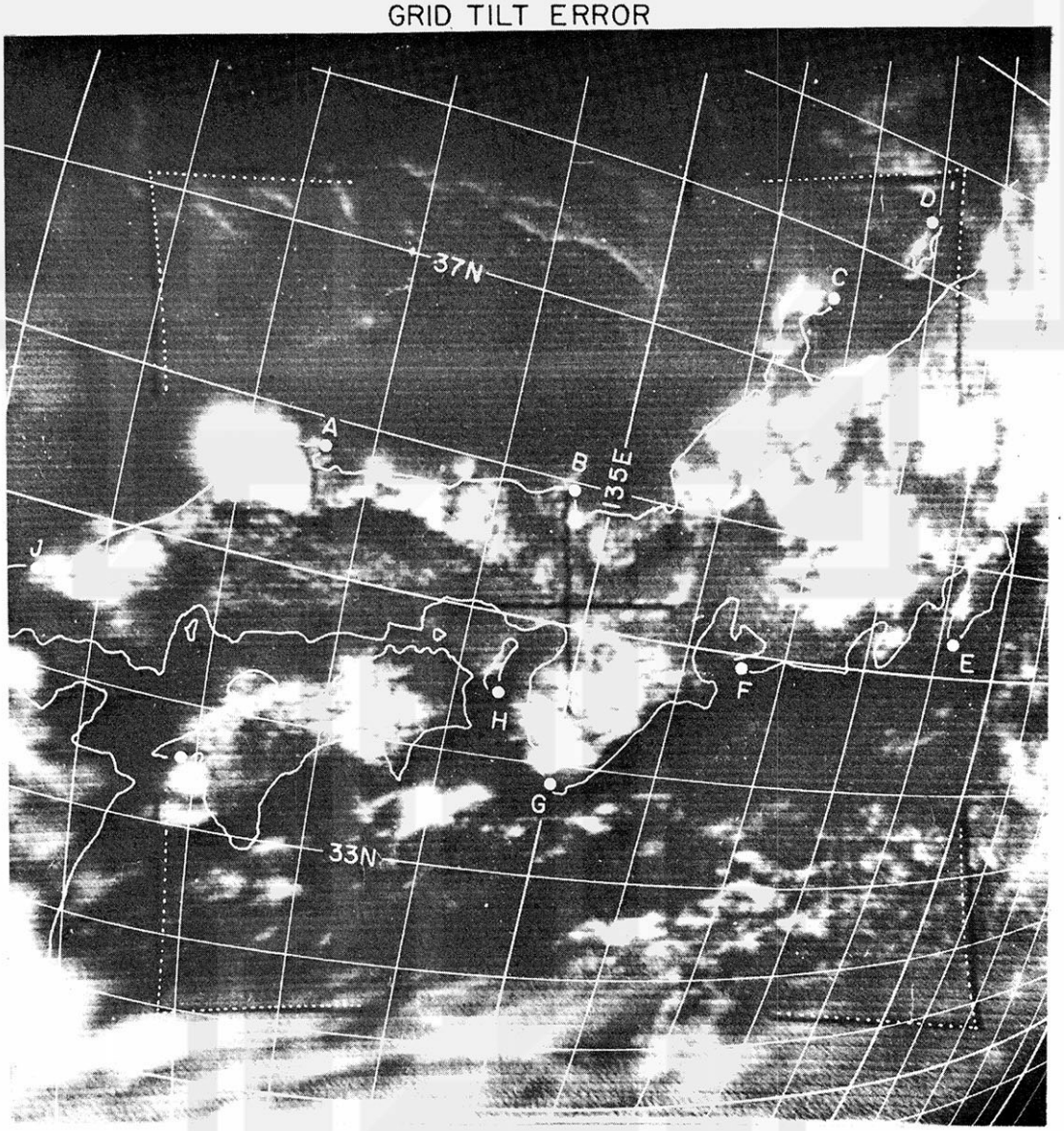
L7

CLOUD PHOTOGRAPH AUG. 5, 1963

TIROS VII A/O 692 R/O 692

TAPE CAMERA 1

GRID TILT ERROR

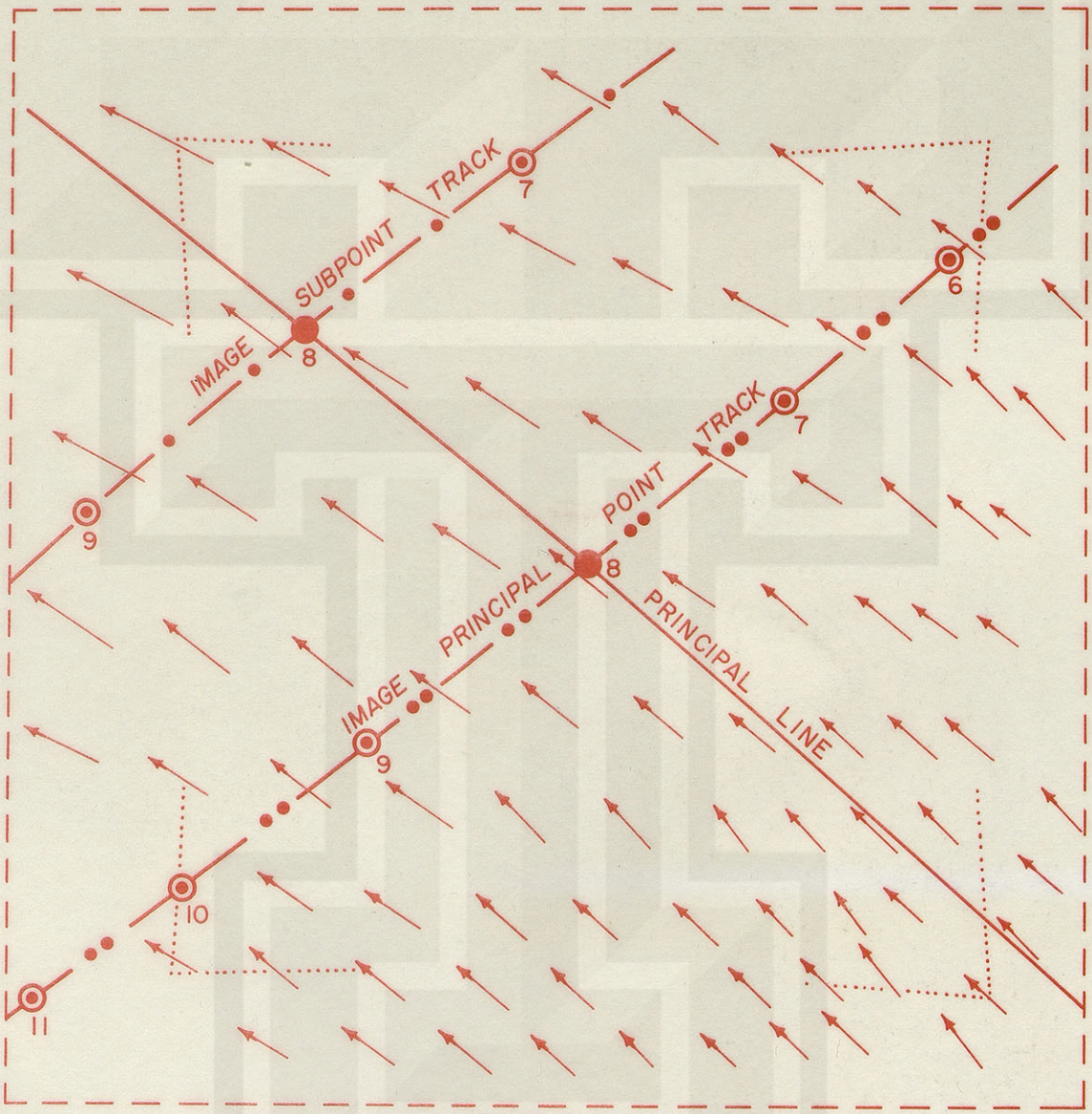


FRAME 8

CORRECT		USED	
TIME = 0525.5 Z	H = 627 km	TIME = 0525.5 Z	H = 627 km
τ = 23.8°	ϕ^{TSP} = 36.0 N	**τ = 18.8°**	ϕ^{TSP} = 36.0 N
α^{PL} = 117.0°	θ^{TSP} = 132.7 E	α^{PL} = 117.0°	θ^{TSP} = 132.7 E

SMRP, University of Chicago

VECTOR TILT ERROR



TAPE 8

VECTOR SHIFT REQUIRED TO ADJUST A PICTURE GRIDDING ERROR INDUCED BY USING AN IMAGE TILT 5° TOO LOW FOR GRID CONSTRUCTION.

$\tau_{ACTUAL} = 23.8°$ $\tau_{USED} = 18.8°$

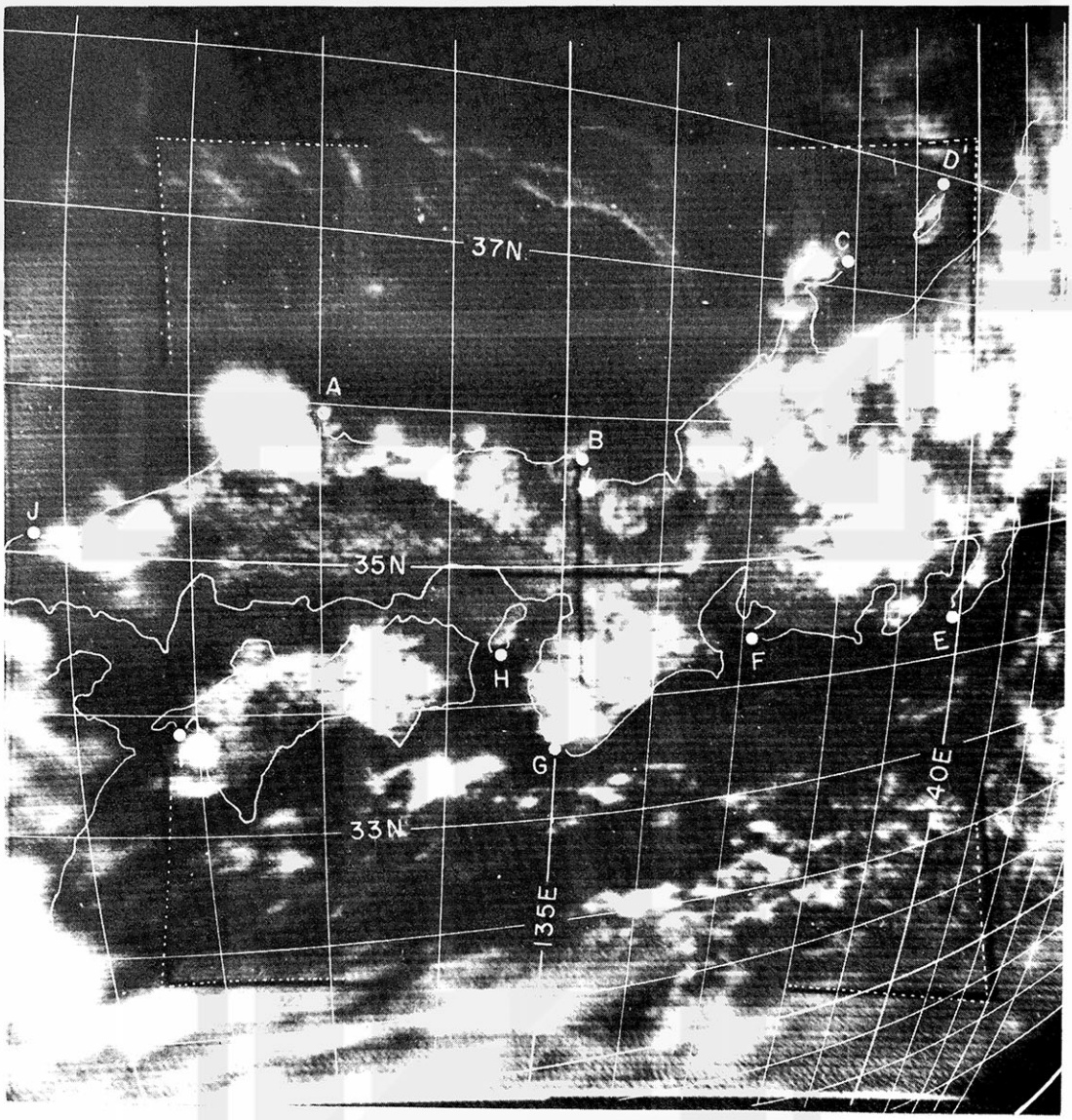
L 9

CLOUD PHOTOGRAPH AUG. 5, 1963

TIROS VII A/O 692 R/O 692

TAPE CAMERA I

GRID AZIMUTH ERROR I



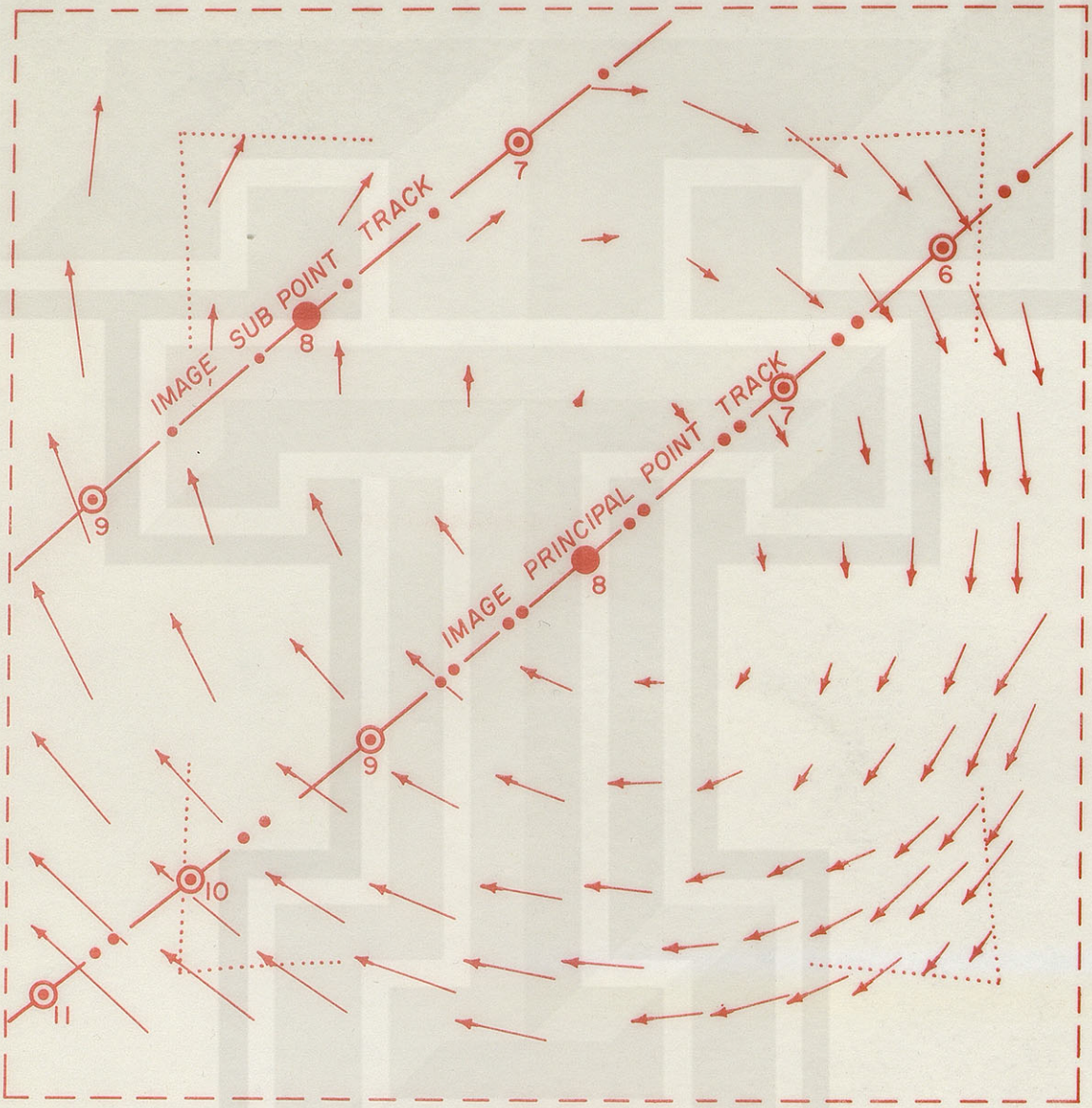
FRAME 8

CORRECT GRID, INCORRECT PRINCIPAL LINE ALIGNMENT

CORRECT		USED	
TIME = 0525.5 Z	H = 627 km	TIME = 0525.5 Z	H = 627 km
τ = 23.8°	ϕ^{TSP} = 36.0 N	τ = 23.8°	ϕ^{TSP} = 36.0 N
α^{PL} = 117.0°	θ^{TSP} = 132.7 E	α^{PL} = 127.0°	θ^{TSP} = 132.7 E

SMRP, University of Chicago

VECTOR AZIMUTH ERROR I



TAPE 8

VECTOR SHIFT REQUIRED TO ADJUST A PICTURE GRIDDING ERROR INDUCED BY ALIGNING A CORRECTLY CONSTRUCTED PICTURE GRID ALONG AN INCORRECT IMAGE PRINCIPAL LINE AZIMUTH.

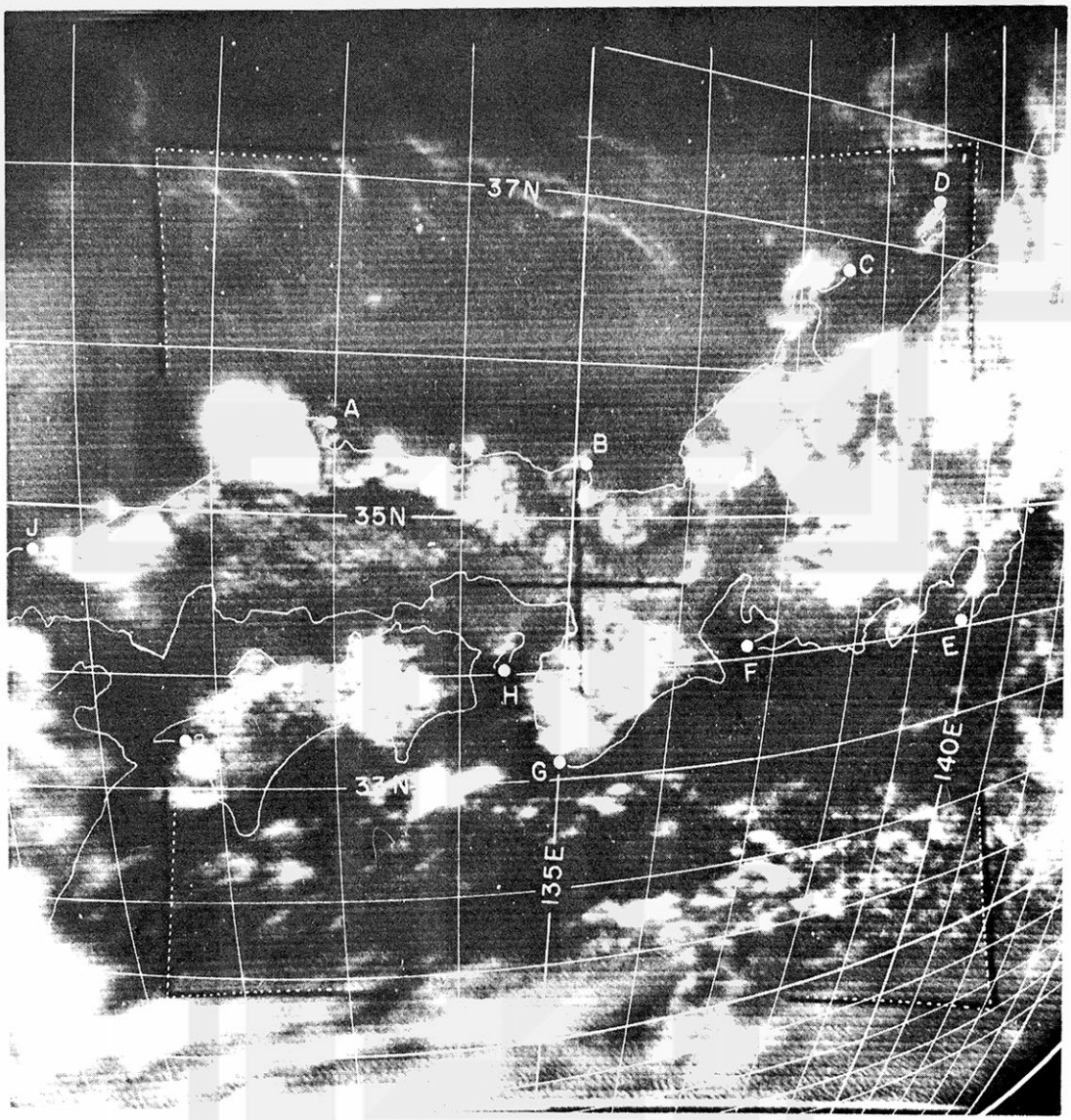
$\alpha^{PL}_{ACTUAL} = 117.0°$ $\alpha^{PL}_{USED} = 127.0°$

CLOUD PHOTOGRAPH AUG. 5, 1963

TIROS VII A/O 692 R/O 692

TAPE CAMERA I

GRID AZIMUTH ERROR II



FRAME 8

INCORRECT GRID, CORRECT PRINCIPAL LINE ALIGNMENT

CORRECT		USED	
TIME = 0525.5 Z	H = 627 km	TIME = 0525.5 Z	H = 627 km
τ = 23.8°	ϕ^{TSP} = 36.0 N	τ = 23.8°	ϕ^{TSP} = 36.0 N
α^{PL} = 117.0°	θ^{TSP} = 132.7 E	**α^{PL} = 127.0°**	θ^{TSP} = 132.7 E

VECTOR AZIMUTH ERROR II

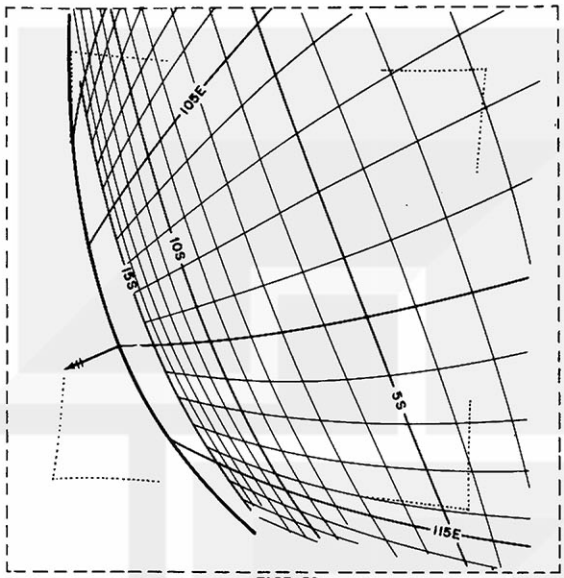
TAPE 8

VECTOR SHIFT REQUIRED TO ADJUST A PICTURE GRIDDING ERROR INDUCED BY COMPUTING THE PICTURE GRID USING AN INCORRECT AZIMUTH OF THE IMAGE PRINCIPAL LINE BUT ALIGNING THE CONSTRUCTED GRID PROPERLY.

$\alpha^{PL}_{ACTUAL} = 117.0°$ $\alpha^{PL}_{USED} = 127.0°$

TIROS VII A/O 692 R/O 692 PICTURE GRID
TAPE CAMERA I

VECTOR TIME ERROR



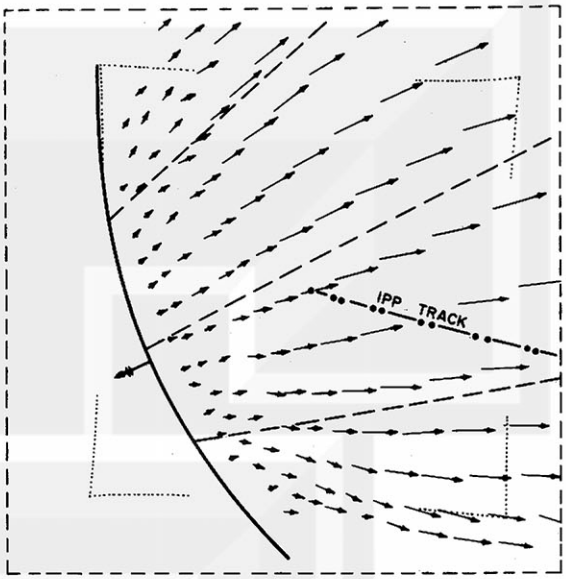
TAPE 32

FRAME 32 TIME = 0513.5 Z

τ = 44.0° ϕ^{TSP} = 0.7° S

α^{PL} = 177.0° θ^{TSP} = 108.6E

H = 631 km

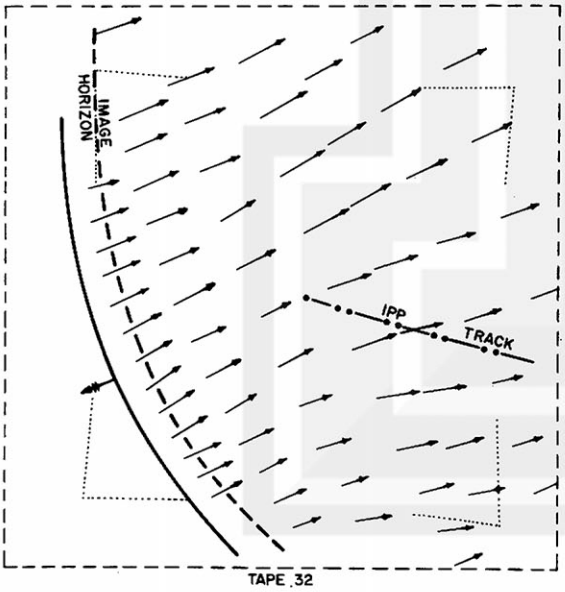


TAPE 32

VECTOR SHIFT REQUIRED TO ADJUST A PICTURE GRIDDING ERROR INDUCED BY USING AN INCORRECT PICTURE EXPOSURE TIME OF 15 SECONDS.

EXPOSURE TIME = 0513.5 Z ACTUAL EXPOSURE TIME = 0513.75 Z USED

VECTOR TILT ERROR

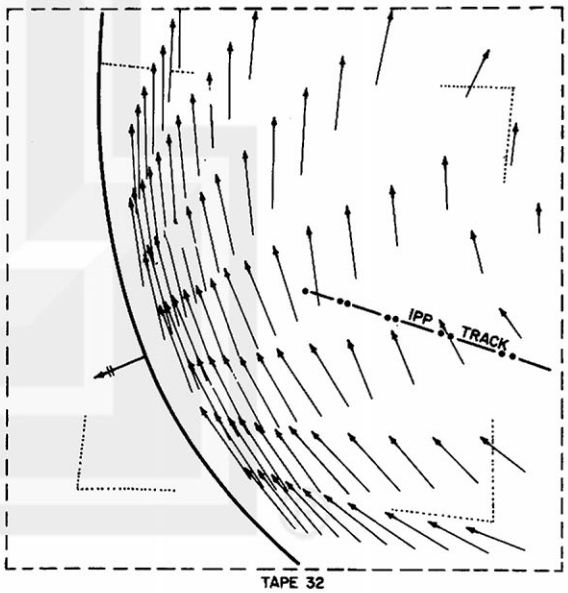


TAPE 32

VECTOR SHIFT REQUIRED TO ADJUST A PICTURE GRIDDING ERROR INDUCED BY USING AN IMAGE TILT 5° TOO LOW FOR GRID CONSTRUCTION.

τ_{ACTUAL} = 44.0° τ_{USED} = 39.0°

VECTOR AZIMUTH ERROR II



TAPE 32

VECTOR SHIFT REQUIRED TO ADJUST A PICTURE GRIDDING ERROR INDUCED BY COMPUTING THE PICTURE GRID USING AN INCORRECT AZIMUTH OF THE IMAGE PRINCIPAL LINE BUT ALIGNING THE CONSTRUCTED GRID PROPERLY.

α^{PL}_{ACTUAL} = 177° α^{PL}_{USED} = 187°