# IR TRI-SPECTRAL CLOUD PHASE DELINEATION

Part of the cloud product MOD06
Parameter 1764

**IR Cloud Phase Algorithm:** Based upon the differential particle absorption and differential atmospheric absorption that takes place between 8, 11 and 12 micron spectral regions.

The radiative properties of cloud are defined by their single-scattering and geometric characteristics:

the index of refraction $m = n_r - n_i$
main component of the absorption coefficient $K(\lambda) = 4\pi n_i / \lambda$
cloud particle size distribution
particle shape distribution

**Remote sensing of clouds must also take into consideration the amospheric absorption. In a clear atmosphere, water vapor absorption varies over the window region.**

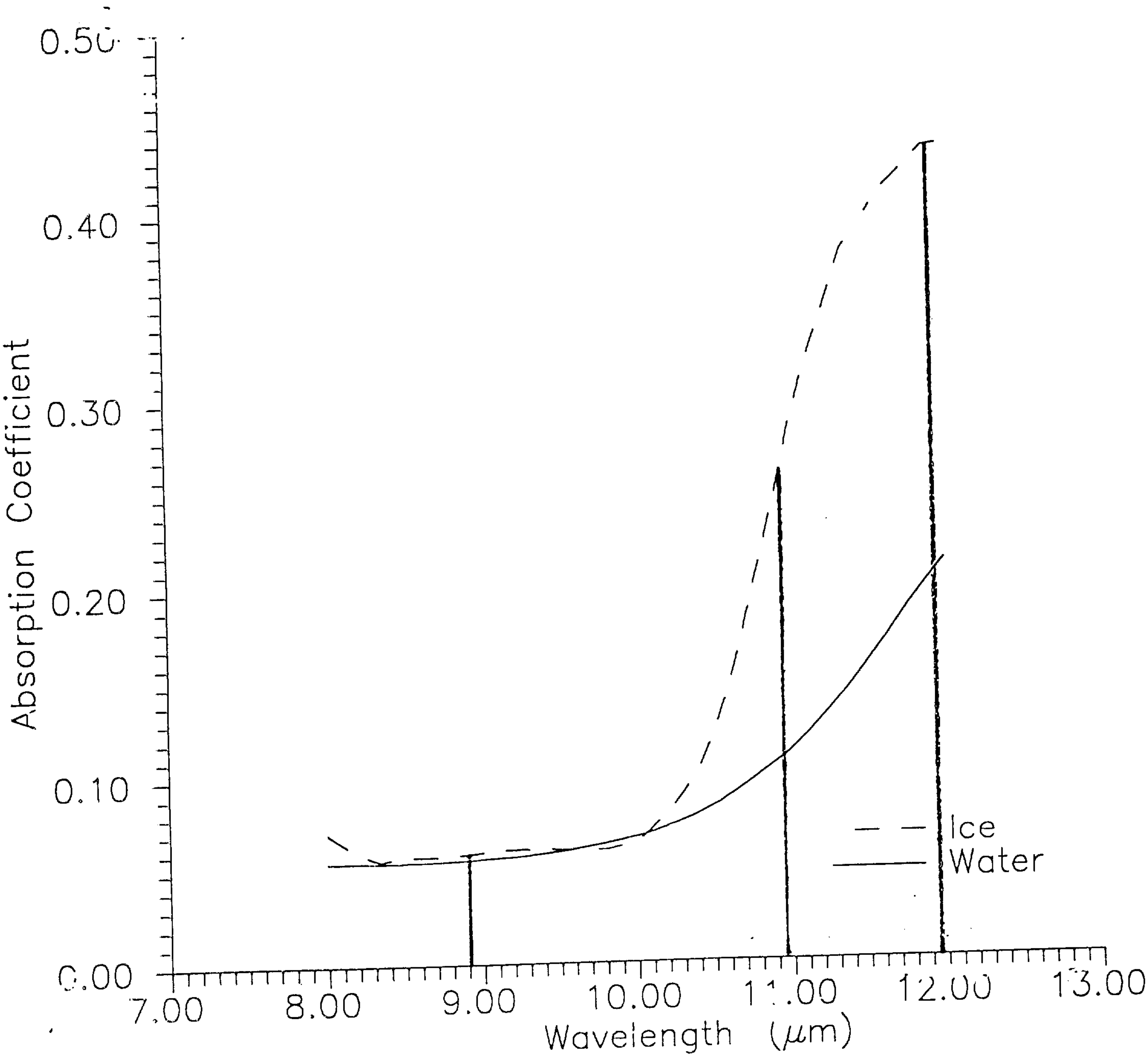
**Combining results of ice/water absorption and atmospheric absorption leads to basis of tri-spectral technique:**

- From 8-9 microns, ice/water particle absorption is at a minimum, while water vapor absorption is relatively strong. The reverse is true for 11-12 microns. Therefore, large positive 8-11 micron BTDIF indicate cirrus, while near zero or negative BTDIF indicate clear regions.

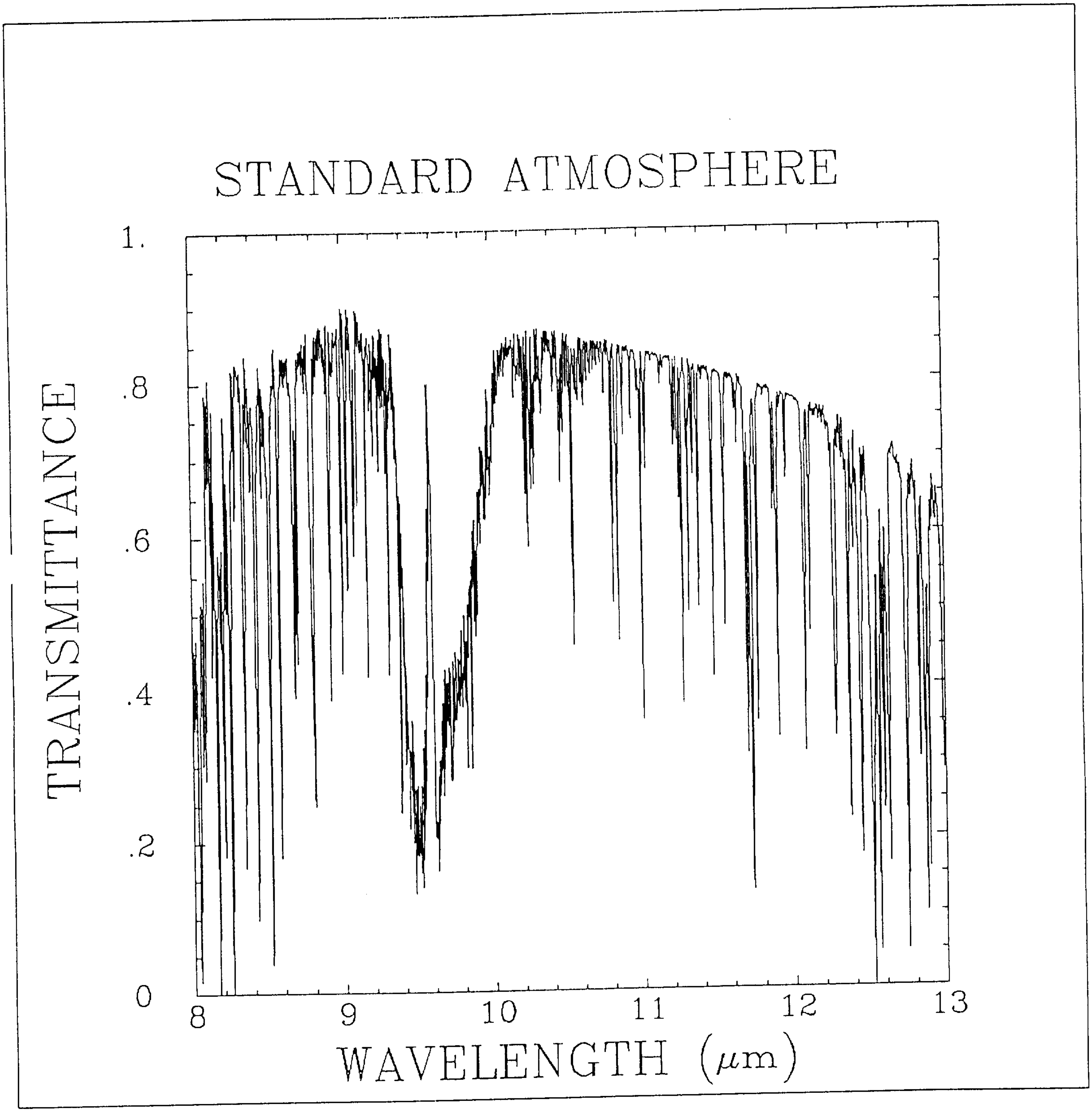
- A third band in the 12 micron range will enable cloud phase delineation. Water particle absorption increases more between 11 and 12 microns than between 8 and 11 microns, while the increase of ice particle absorption is greater between 8 and 11 microns than between 11 and 12 microns.

- Ice and water cloud will separate in a scatter diagram of 8 minus 11 micron versus 11 minus 12 micron BTDIF. Ice clouds will group along a slope greater than one, and water clouds less than one. Mixed phase or partial radiometer filled ice over water clouds will exhibit characteristics of both ice and water clouds in this format, grouping in between the ice and water slopes.

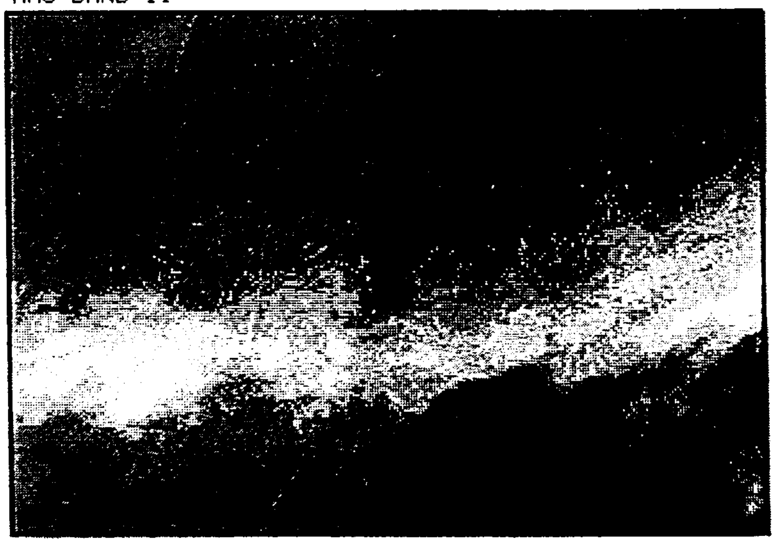
**Tri-spectral technique involves identifying cloud phase based on a scatter diagram of 8-11 versus 11-12 micron BTDIF.**



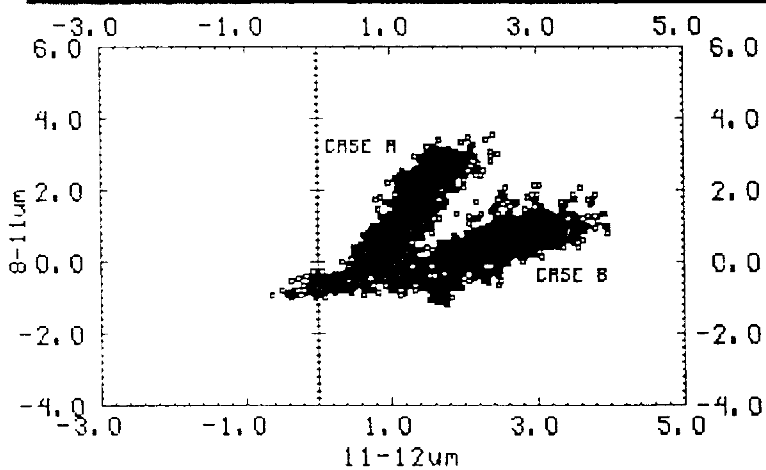
0.50
0.40
0.30
0.20
0.10
0.00
Absorption Coefficient
7.00
8.00
9.00
10.00
11.00
12.00
13.00
Wavelength (μm)
Ice
Water


STANDARD ATMOSPHERE
TRANSMITTANCE
1.
.8
.6
.4
.2
0
8
9
10
11
12
13
WAVELENGTH ($\mu$m)

**CASE A - THIN ICE CLOUD**
MAS BAND 11



**CASE B - WATER CLOUD**
MAS BAND 11




# SPECTRAL SIGNATURE OF CLOUD PROPERTIES

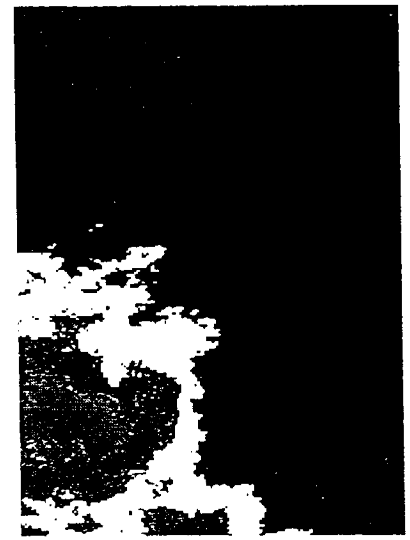
AS DETERMINED BY
BRIGHTNESS TEMPERATURE DIFFERENCING
OF THE MODIS AIRBORNE SIMULATOR
INFRARED CHANNELS

MAS FLIGHT
5 DECEMBER 1991

# 5 DEC 1991
# MAS TRACK E

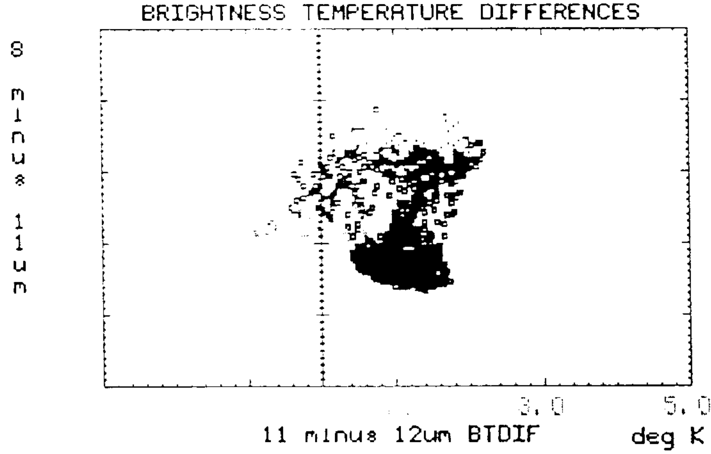
## SPECTRAL CLOUD SIGNATURES

**MAS 11um**



**MAS ENHANCED 11um**

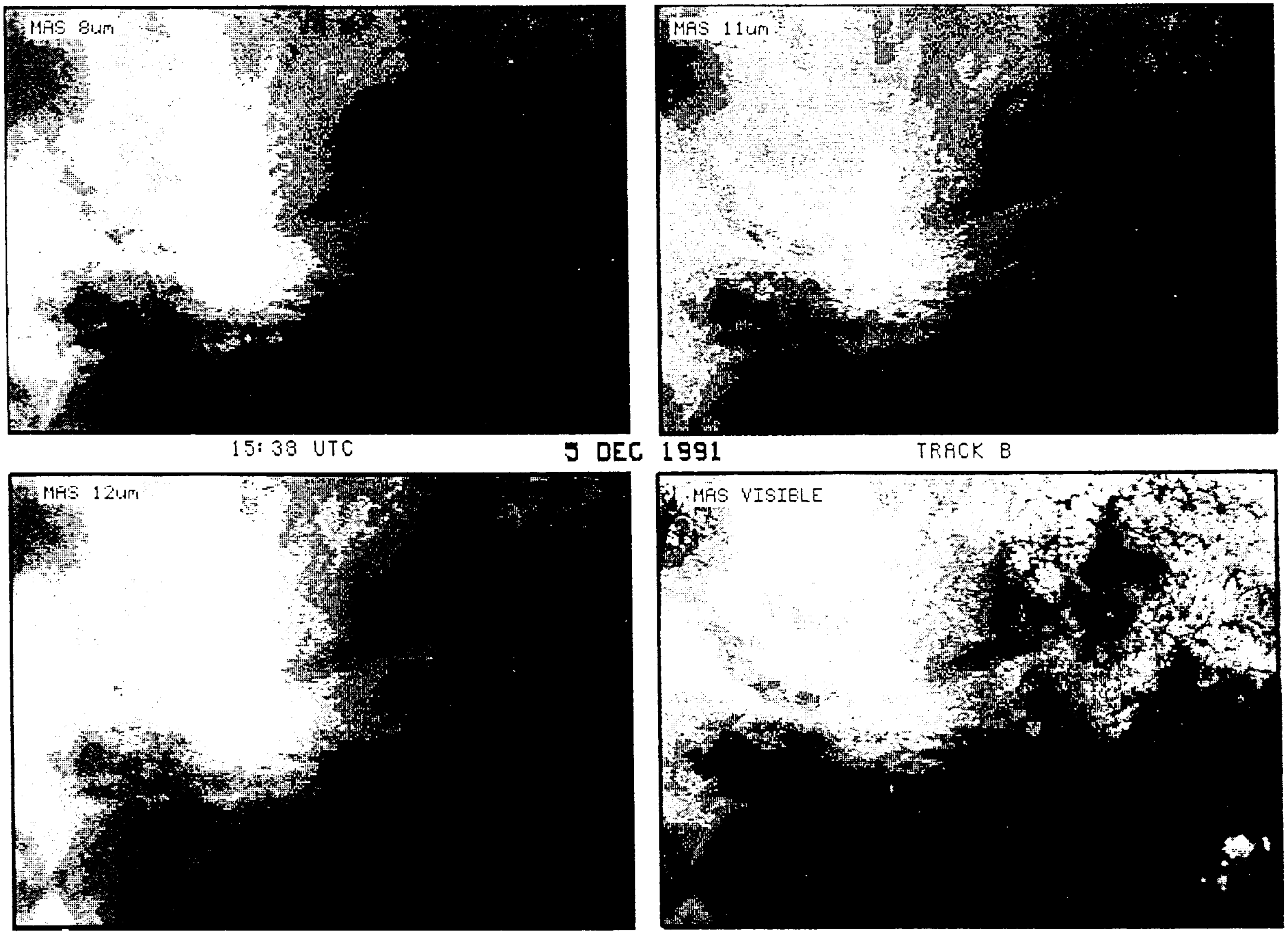
BRIGHTNESS TEMPERATURE DIFFERENCES

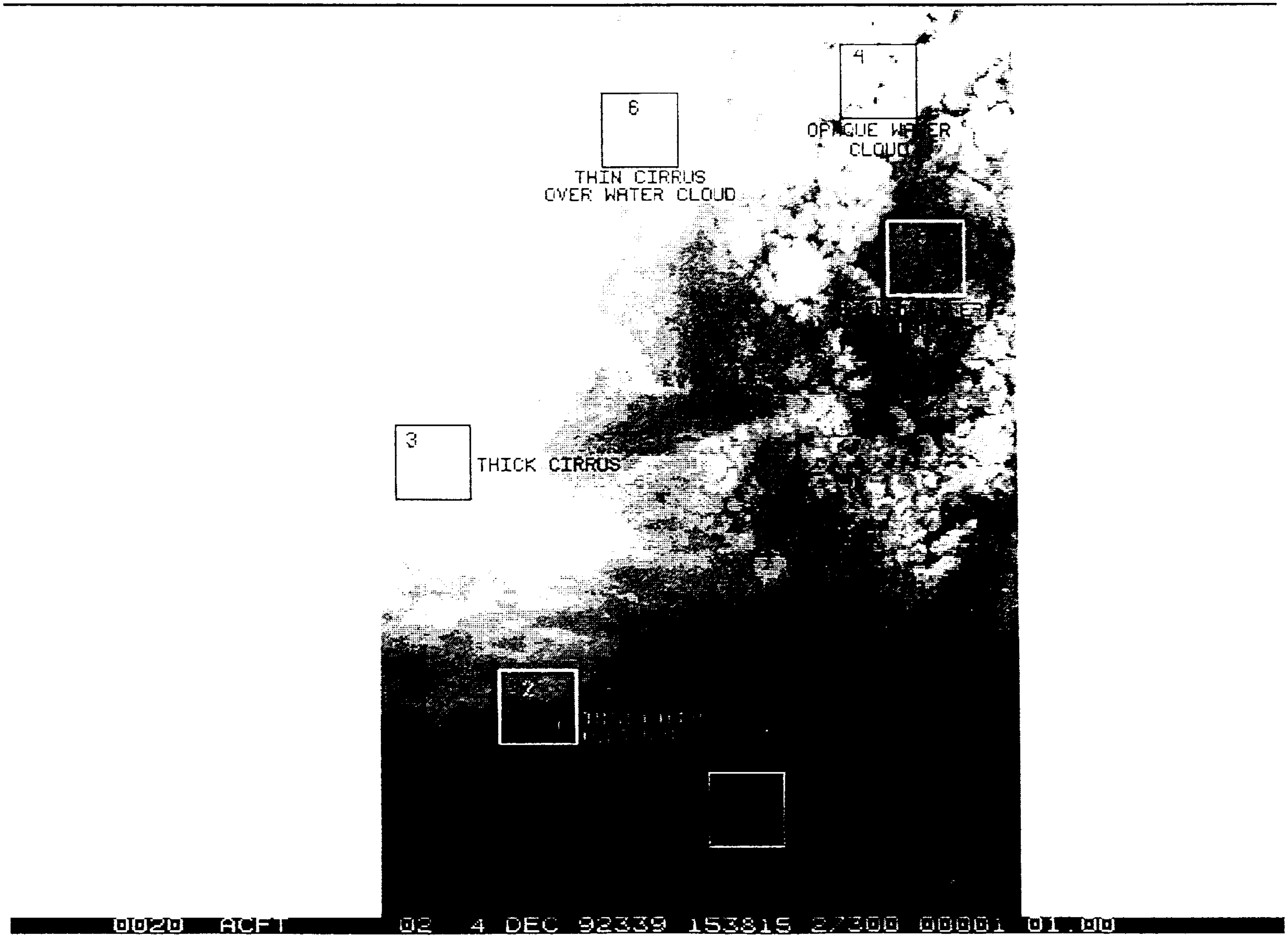


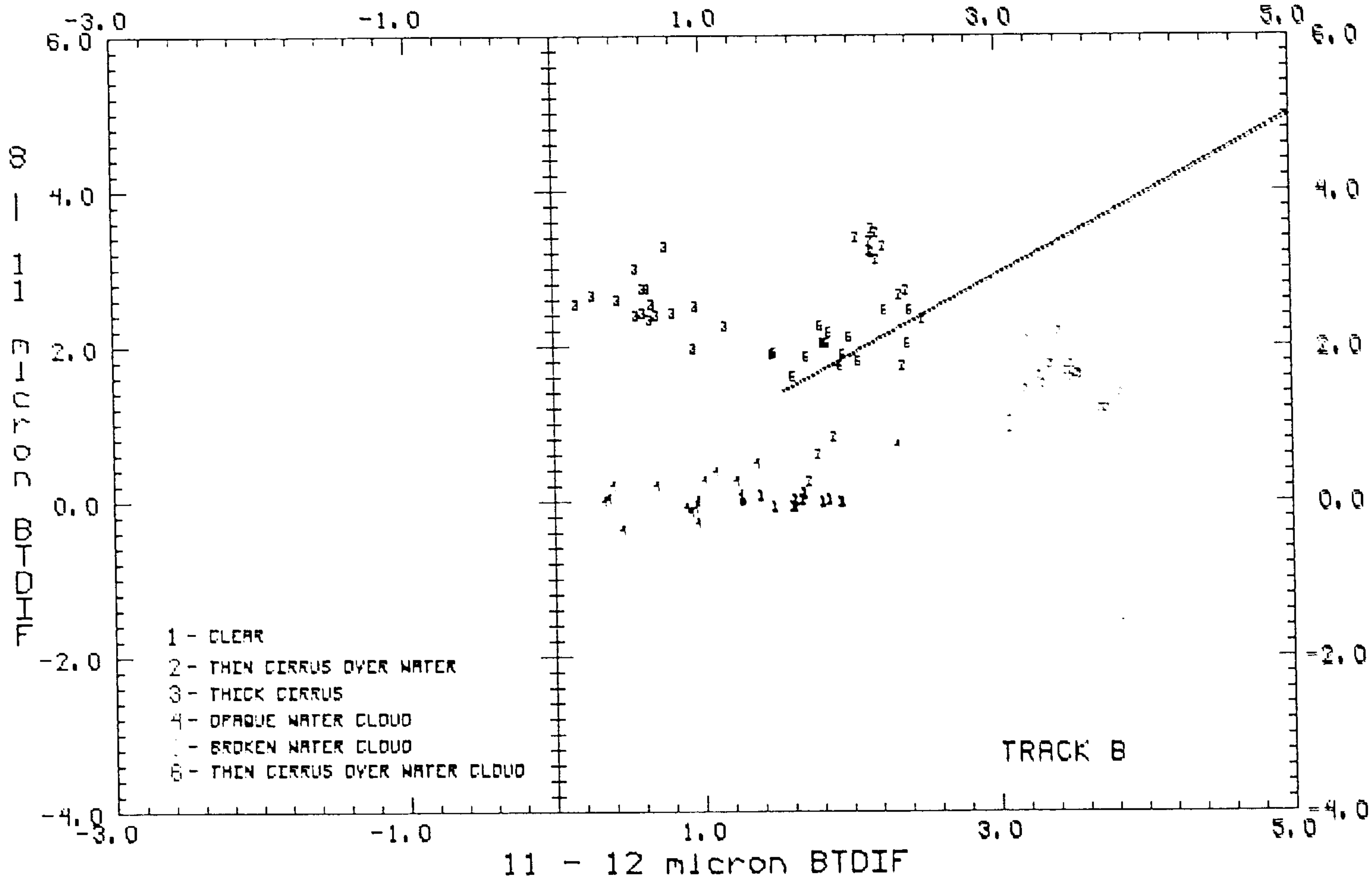

11um BRIGHTNESS TEMPERATURE

- 290 - 305K
- 275 - 290K
- 260 - 275K
- 245 - 260K
- 230 - 245K
- 215 - 230K

* COLOR CATEGORIZATION APPLIES TO BOTH THE SCATTER DIAGRAM AND THE ENHANCED 11um IMAGE

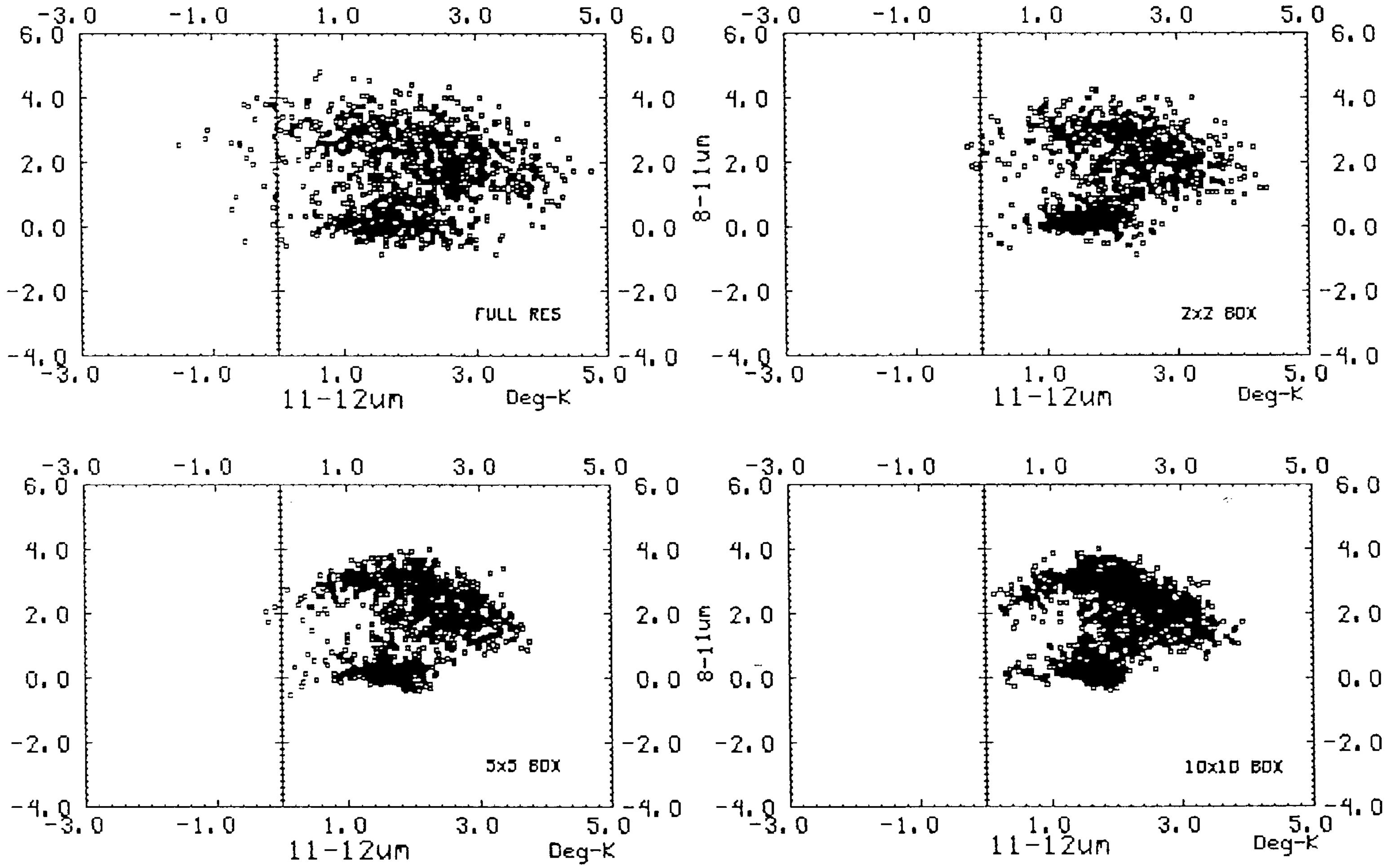

MAS 8um
MAS 11um
15:38 UTC
5 DEC 1991
TRACK B
MAS 12um
MAS VISIBLE


4
6
THIN CIRRUS
OVER WATER CLOUD
3
THICK CIRRUS
2
0020 ACFT 02 4 DEC 92339 153815 27300 00001 01.00

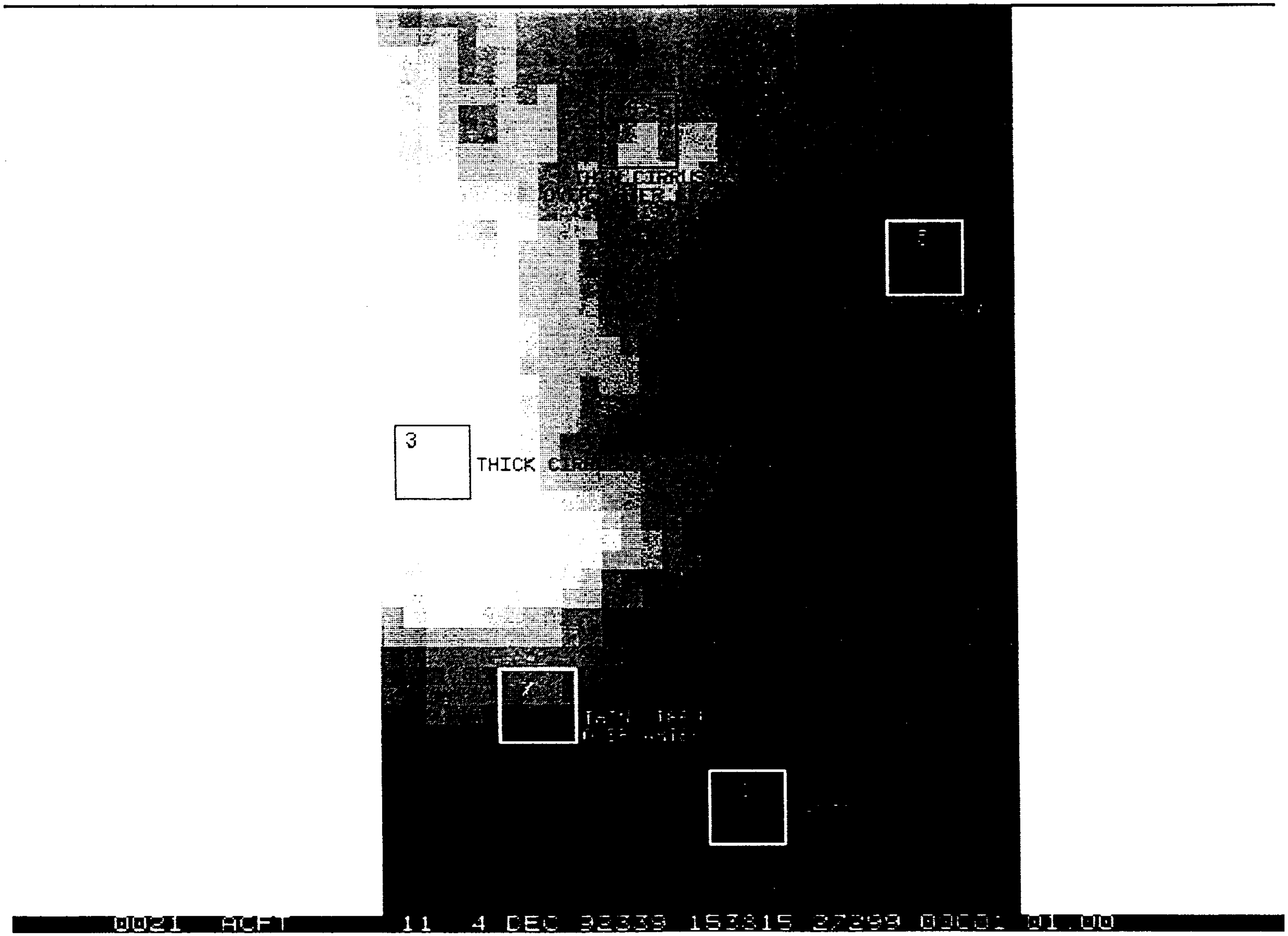


1 - CLEAR
2 - THIN CIRRUS OVER WATER
3 - THICK CIRRUS
4 - OPAQUE WATER CLOUD
5 - BROKEN WATER CLOUD
6 - THIN CIRRUS OVER WATER CLOUD
TRACK B
8 - 11 micron BTDIF
11 - 12 micron BTDIF
-3.0
-1.0
1.0
3.0
5.0
6.0
4.0
2.0
0.0
-2.0
-4.0

EFFECTS OF DATA AVERAGING ON BT DIFFERENCING



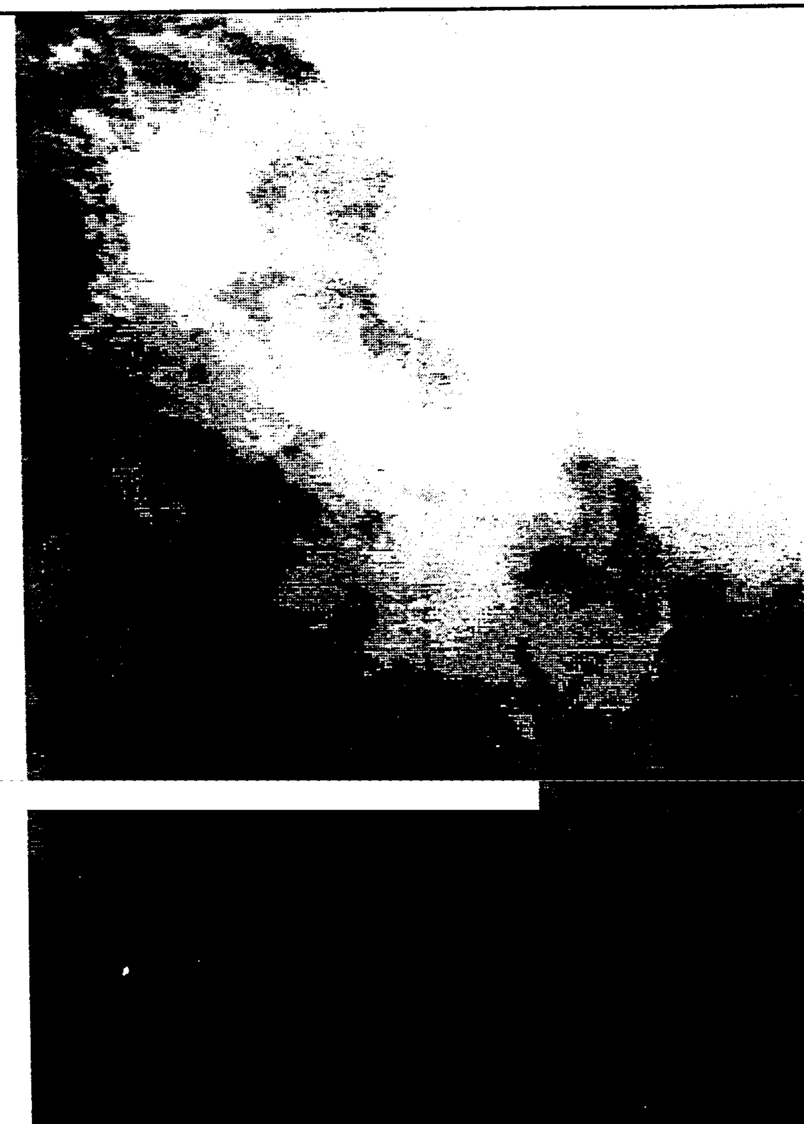

5 DEC 1991 CASE B


3
THICK
0021 ACFT 11 4 DEC 92339 153815 27299 00001 01.00

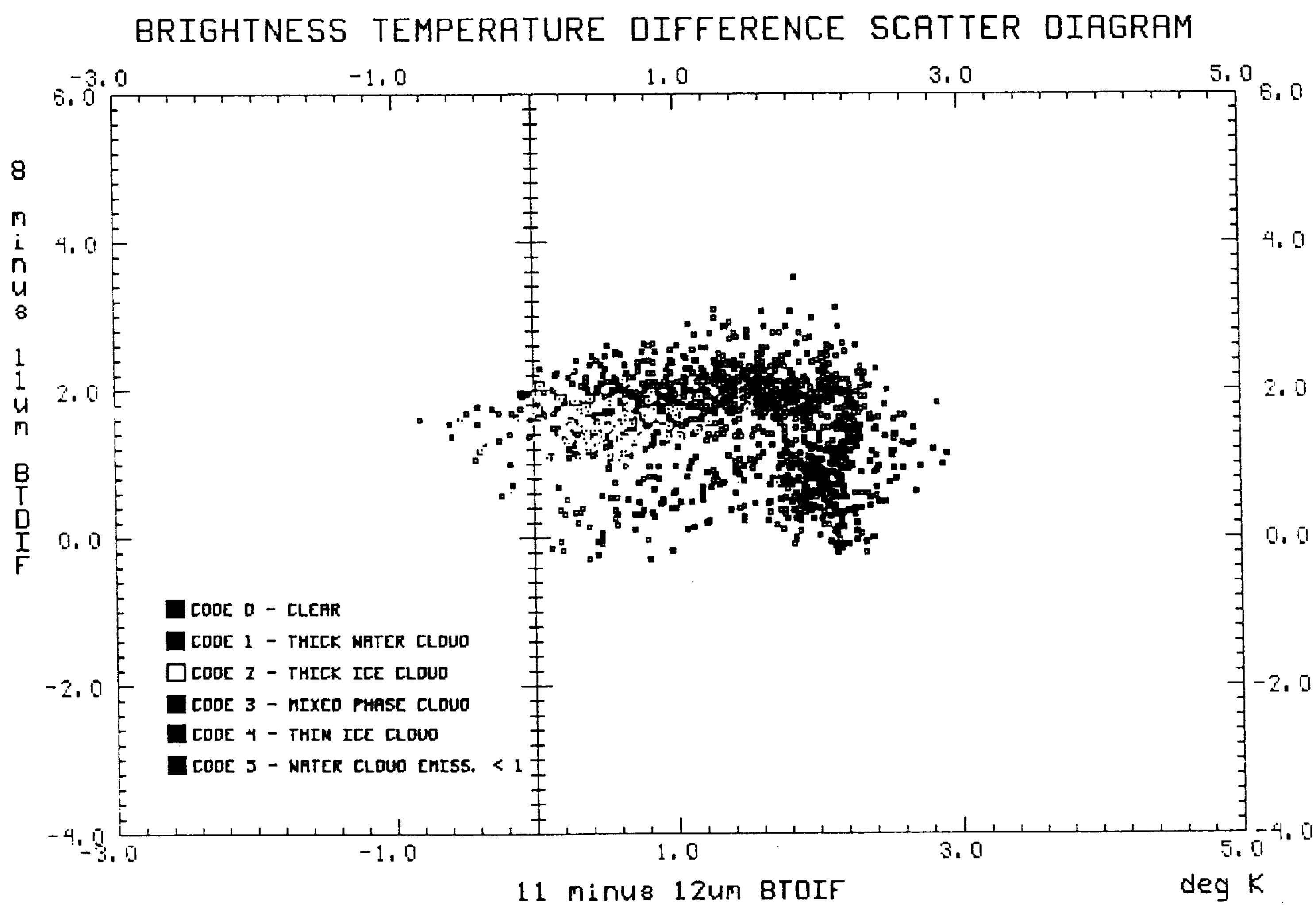
| Tri-Spectral Technique |
|---|
| Clear over water (code 0)<br>if 8$\mu$m radiance SD < .5 and<br>if 8–11$\mu$m BTDIF < .5 and<br>if 11–12$\mu$m BTDIF < 2.4 and<br>if 11$\mu$m BT > 277 K |
| Water cloud with emissivity near one (code 1)<br>if 8$\mu$m radiance SD < .5 and<br>if clear 8–11$\mu$m threshold not met and<br>if 11–12$\mu$m BTDIF threshold not met and<br>if 260 K < 11$\mu$m BT < 280 K |
| Ice cloud with emissivity near one (code 2)<br>if 8$\mu$m radiance SD < .5 and<br>if clear 8–11$\mu$m threshold not met and<br>if 11–12$\mu$m BTDIF threshold not met and<br>if 11$\mu$m BT < 260 K |
| Mixed phase cloud (code 3)<br>if 8$\mu$m radiance SD > .5 and<br>if 8–11$\mu$m BTDIF > 1.25 and<br>if the ABS of 8–11$\mu$m BTDIF minus 11–12$\mu$m BTDIF < .3 |
| Ice cloud with emissivity less than one (code 4)<br>if 8$\mu$m radiance SD > .5 and<br>if 8–11$\mu$m BTDIF minus 11–12$\mu$m BTDIF > .3 |
| Water cloud with emissivity less than one (code 5)<br>if 8$\mu$m radiance SD > .50 and<br>if 8–11$\mu$m BTDIF minus 11–12$\mu$m BTDIF < .3 |

Table 2: Thresholds of the tri-spectral technique applied to 10x10 pixel areas, where SD is the Standard Deviation, BT is the Brightness Temperature, BTDIF is the Brightness Temperature Difference and ABS is the Absolute Value.

MAS FIRE DATA
24 NOV 1991
50m RES. TRACK H
11um IMAGE



0022 ACFT 11 23 NOV 92328 170829 17600 00022 01.00

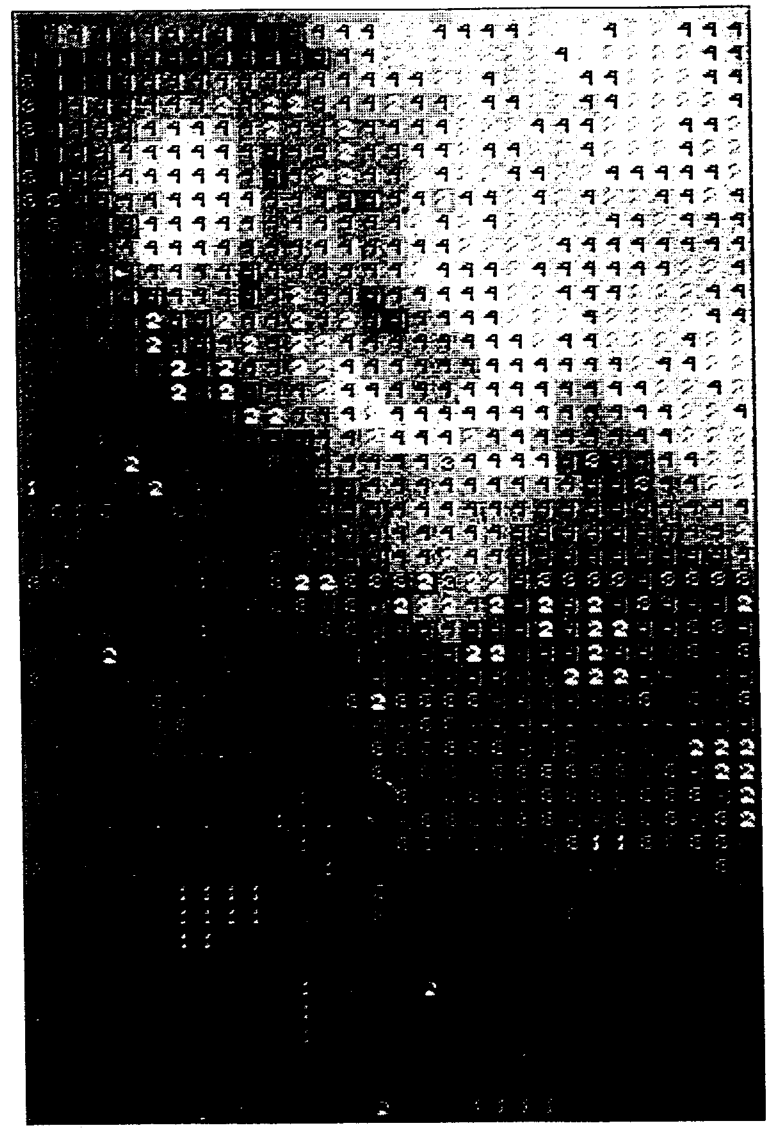



MAS FLIGHT TRACK H 24 NOV 1991

MAS RESULTANT THRESHOLD ALGORITHM CODING

0 - CLEAR
1 - THICK WATER CLOUD
2 - THICK ICE CLOUD
3 - MIXED PHASE CLOUD
4 - THIN ICE CLOUD
5 - WATER CLOUD EMISS. < 1

OVERLAID UPON
24 NOV 1991 TRACK H
11 micron IMAGE SEGMENT



MAS Data 5 Dec 1991

Observation angle: -17 to +17 °

Reflection Function $R_\lambda(\tau_\lambda;\mu,\mu_o,\phi) = \dfrac{\pi I_\lambda(\mu_o,\mu,\phi)}{\mu_o F_{o\lambda}}$

Where $I_\lambda(\mu_o,\mu,\phi)$ is the measured reflected intensity,

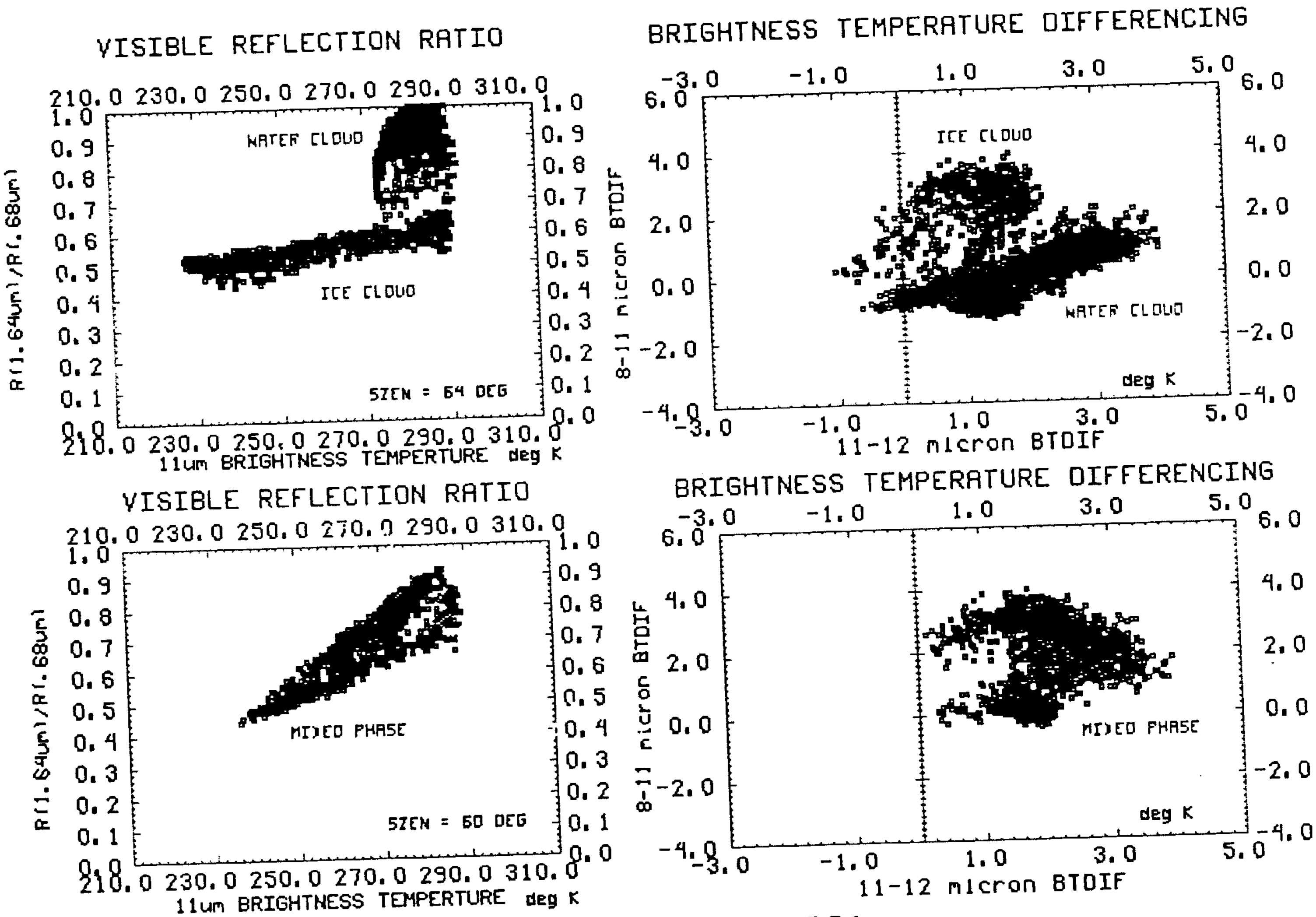
$\tau_\lambda$ the atmospheric or cloud optical thickness at wavelength $\lambda$,

$\mu$ the cosine of the zenith angle with respect to the positive $\tau_\lambda$ direction,

$\mu_o$ the cosine of the solar zenith angle,

$\phi$ the azimuth angle, and

$F_{o\lambda}$ the solar flux density incident at the top of the atmosphere at wavelength $\lambda$.




MAS DATA 5 DEC 1991

# ALGORITHM OUTLINE

**Determine clear sky thresholds from Sea Surface Temperatures:**

Estimate Precipitable Water amount from the Reynolds blended SST using the relationship determined by Stevens (1990)

$$PW = 10.82(\frac{r}{1+\lambda})e^{a(T_{SST}-288K)}$$

where a = 0.0686 and r/1+λ = 0.162.

PW related to BTDIF thresholds by global statistics of HIRS/AVHRR collocated clear sky scenes.

**Determine the nature of the uniform scenes:**

Calculate the standard deviation of the 8.6 micron radiance for a given box size (10x10).

Perform a cluster analysis on boxes with SD < .50 mW/ster/m$^2$/cm$^{-1}$ (aprox. 2X noise) with respect to the 11 micron brightness temperature

$$dist = \sqrt{\Delta sd8.6^2 + \Delta BT11^2}.$$

If cluster center exceeds both 8 minus 11 micron and 11 minus 12 micron BTDIF clear sky thresholds, then cluster is clear. Otherwise, cluster is determined to be uniform (thick) water or thick ice if center falls above the unity slope (ice) or below the unity slope (water) on the BTDIF scatter diagram.

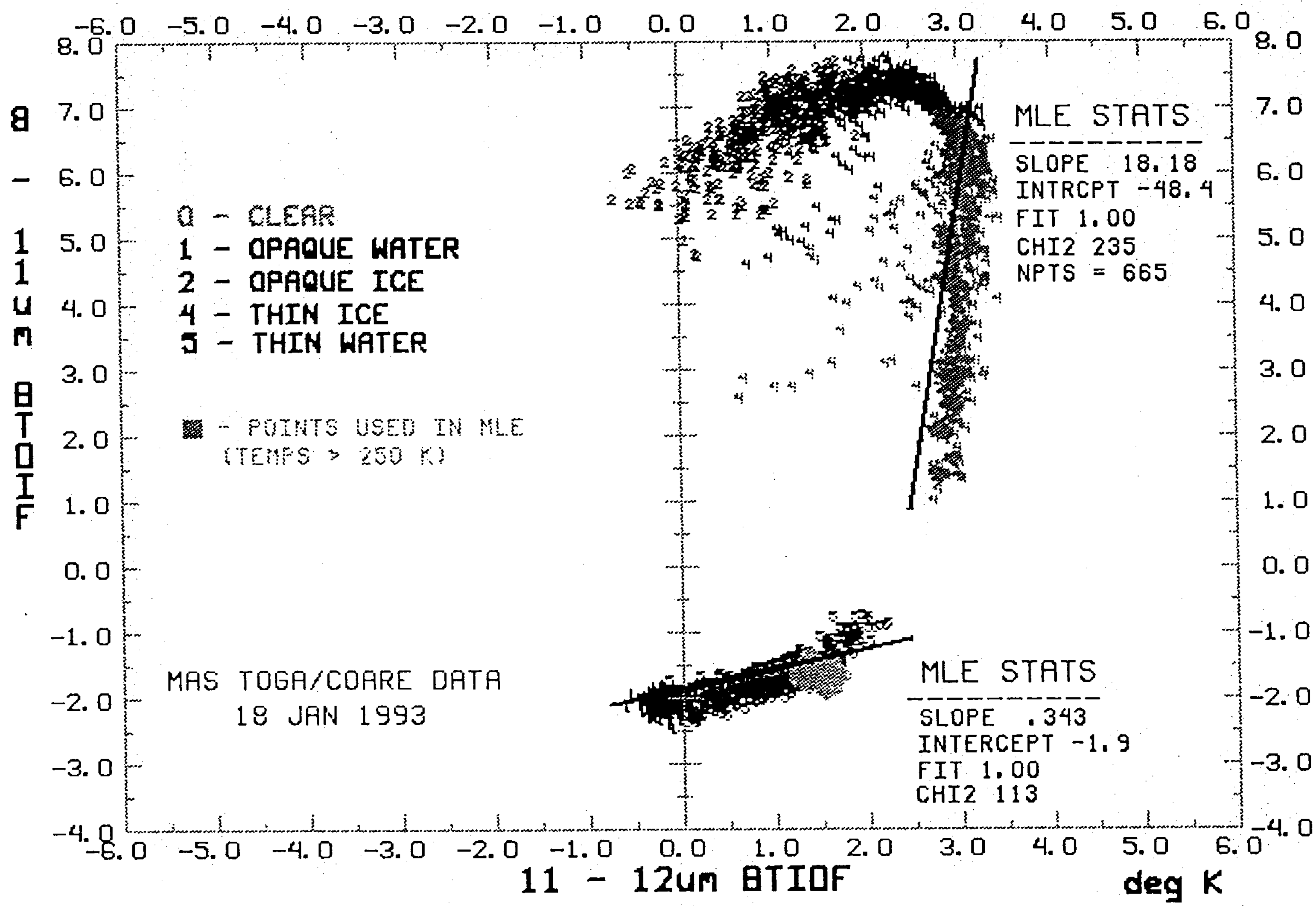
**Determine if the scene is single or multi-phase:**

Perform a least squares fit with errors in two directions on the averaged fov's with an 11 micron BT > 250 K.

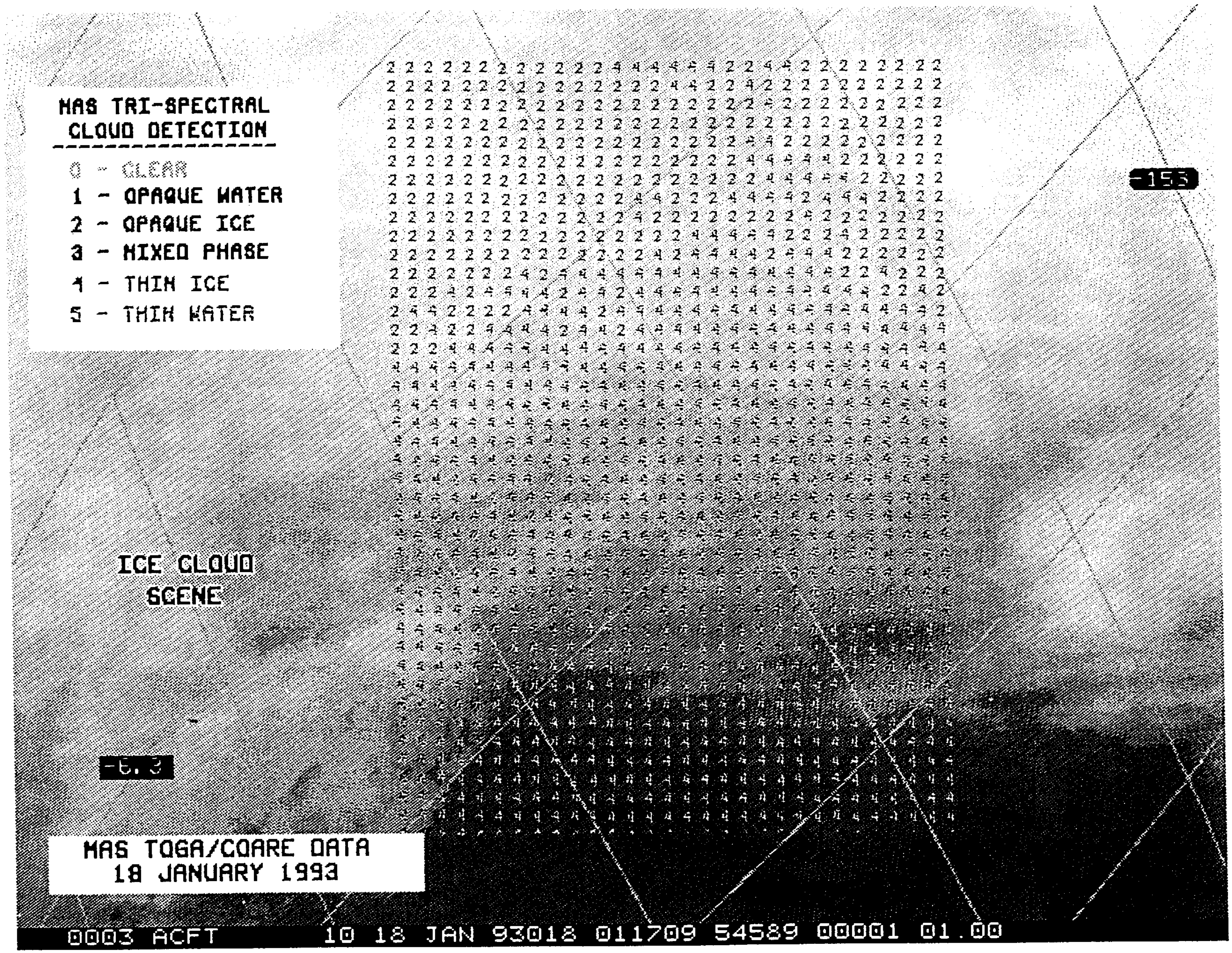
$$\chi^2 = (\frac{1}{\sigma_x^2 + \sigma_y^2})\sum_{i=1}^{N}\frac{(y_i - mx_i - b)^2}{(1-m^2)}.$$

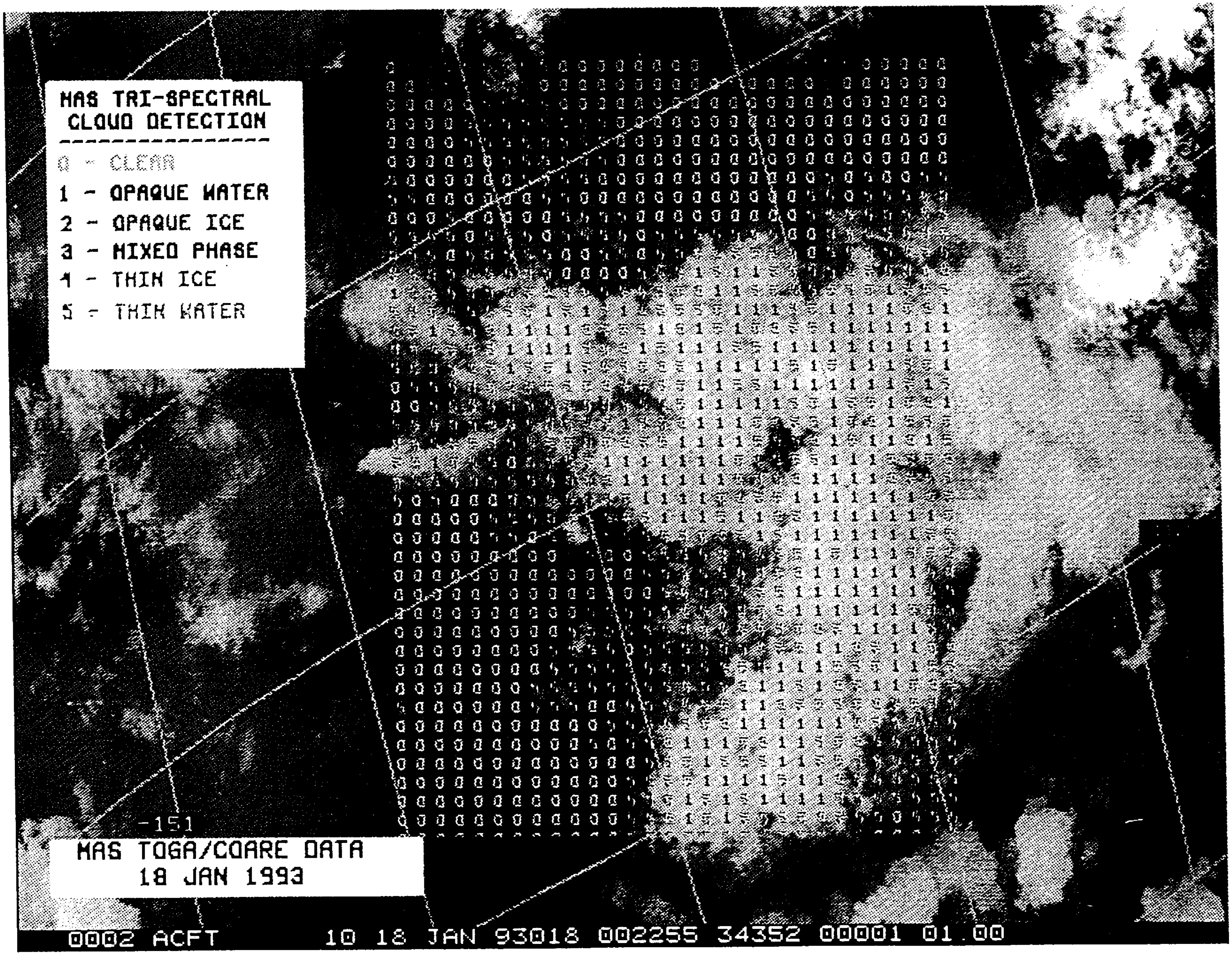
If a gamma fit is good (= 1.00) and the chi squared value is less then the number of fov's then the slope m is tested for single phase clouds. If the slope is greater than 1, then the scene is a single phase ice cloud, if the slope is less than one, it is a single phase water cloud. This overrides any phase determinations made in the previous step.

If a good fit is not found, a multi-phase scene is assumed. From here, each fov is tested for its' proximity to the unity slope. If the fov lies with .3 K of the slope, it is flagged as a mixed scene, otherwise the fov's are coded as previously described.



MLE STATS
SLOPE 18.18
INTRCPT -48.4
FIT 1.00
CHI2 235
NPTS = 665
0 - CLEAR
1 - OPAQUE WATER
2 - OPAQUE ICE
4 - THIN ICE
5 - THIN WATER
▩ - POINTS USED IN MLE
(TEMPS > 250 K)
MAS TOGA/COARE DATA
18 JAN 1993
MLE STATS
SLOPE .343
INTERCEPT -1.9
FIT 1.00
CHI2 113
8 - 11um BTDIF
11 - 12um BTDIF
deg K


MAS TRI-SPECTRAL
CLOUD DETECTION
0 - CLEAR
1 - OPAQUE WATER
2 - OPAQUE ICE
3 - MIXED PHASE
4 - THIN ICE
5 - THIN WATER
-153
ICE CLOUD
SCENE
-6.3
MAS TOGA/COARE DATA
18 JANUARY 1993
0003 ACFT
10 18 JAN 93018 011709 54589 00001 01.00


MAS TRI-SPECTRAL
CLOUD DETECTION
0 - CLEAR
1 - OPAQUE WATER
2 - OPAQUE ICE
3 - MIXED PHASE
4 - THIN ICE
5 - THIN WATER
-151
MAS TOGA/COARE DATA
18 JAN 1993
0002 ACFT 10 18 JAN 93018 002255 34352 00001 01.00