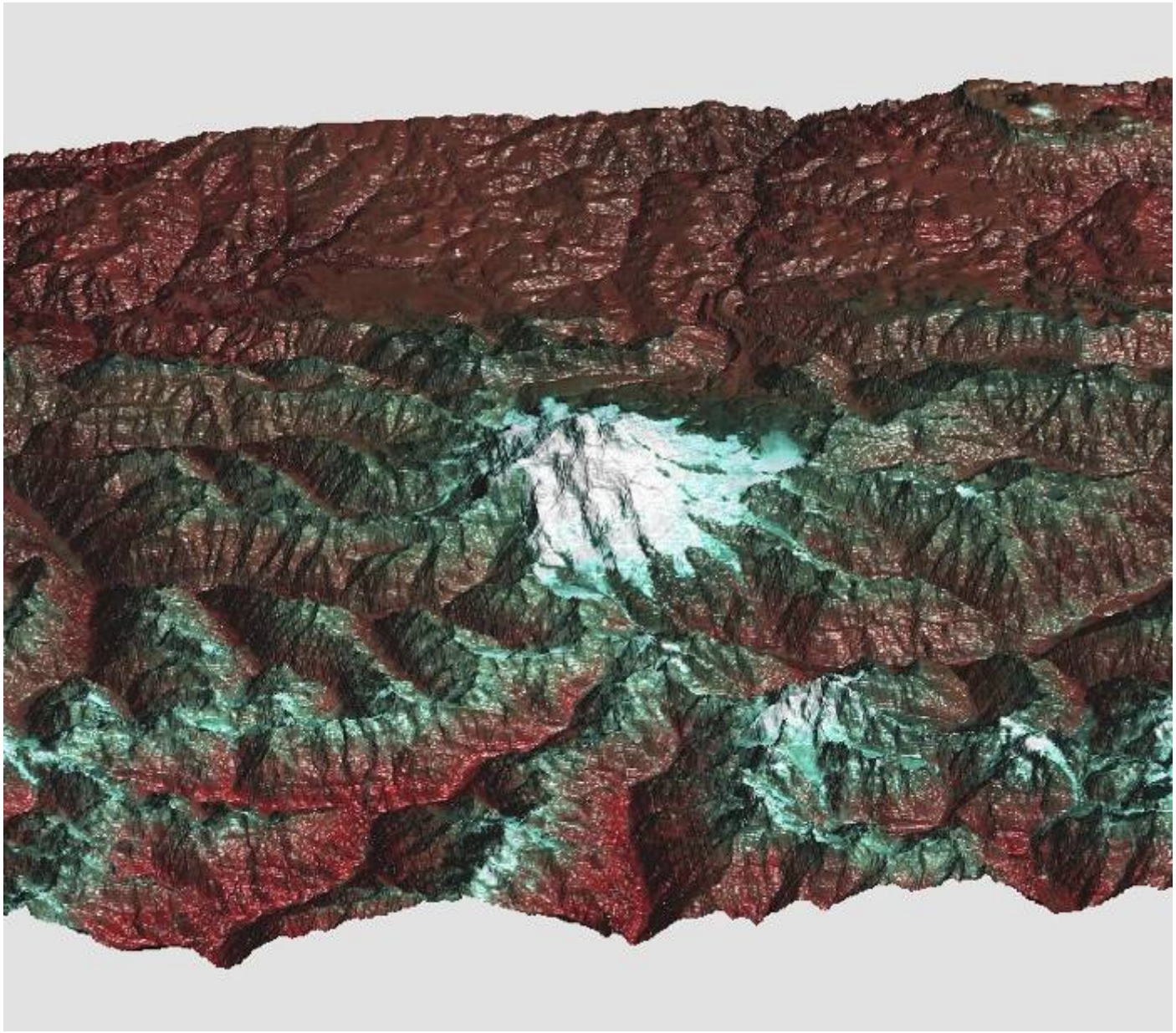
Surface Heat Budgets of the Mt Elbrus region

(design of a student exercise)

Country: Russia
Range: Caucasus
Elevation: 5,642meters
Coordinates: 43.3N, 42.5E
Rank: Highest in Europe



Landsat RGB-432

Land cover types in the region

- Snow covered peaks and ridges
- Barren Ridges
- Forested Lowlands

How does the heat budget
vary among land cover types?

Surface heat budget equation

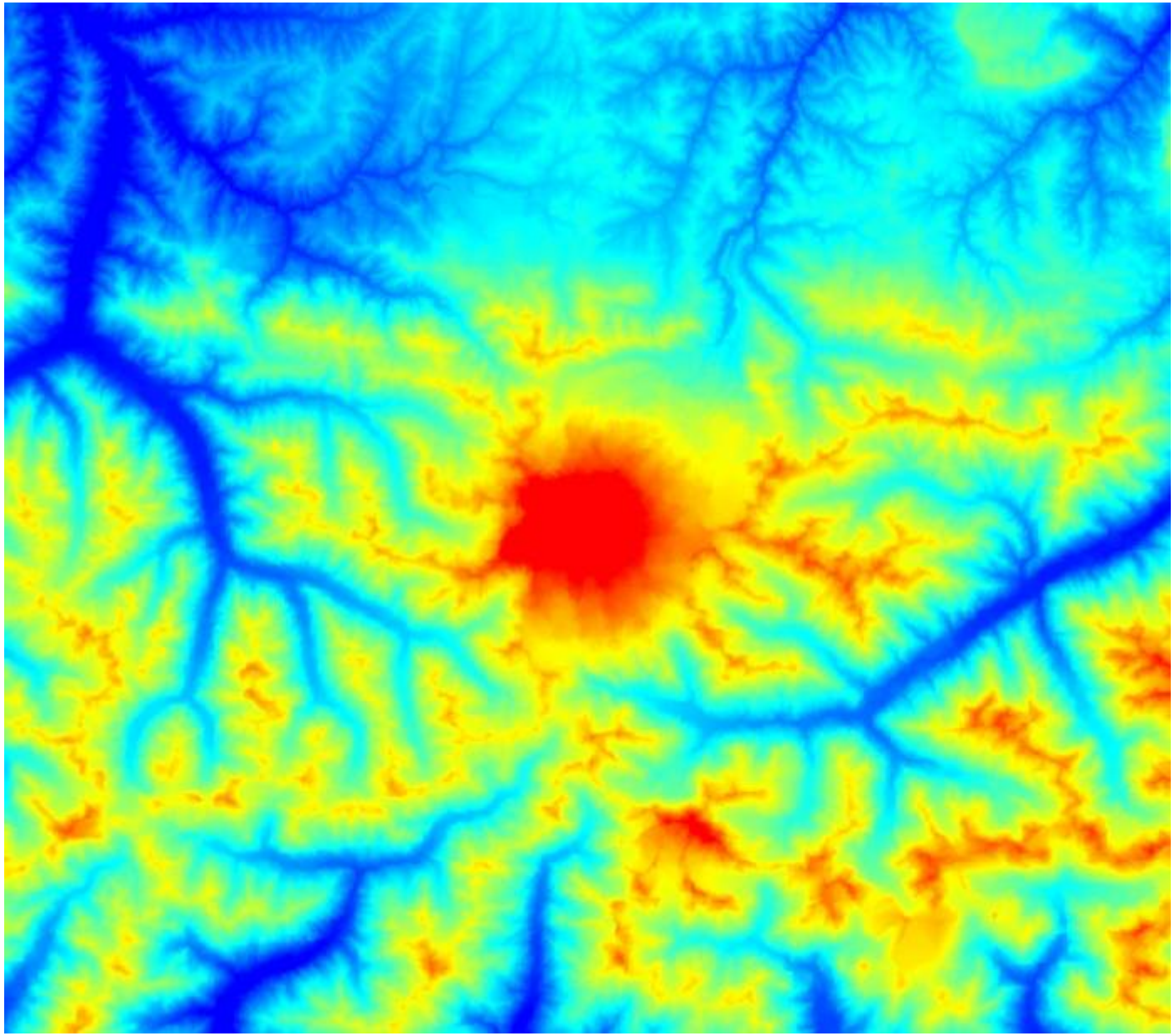
$$MC_H \frac{d\overline{T}_S}{dt} = R_N - F_T$$

term 1 2 3

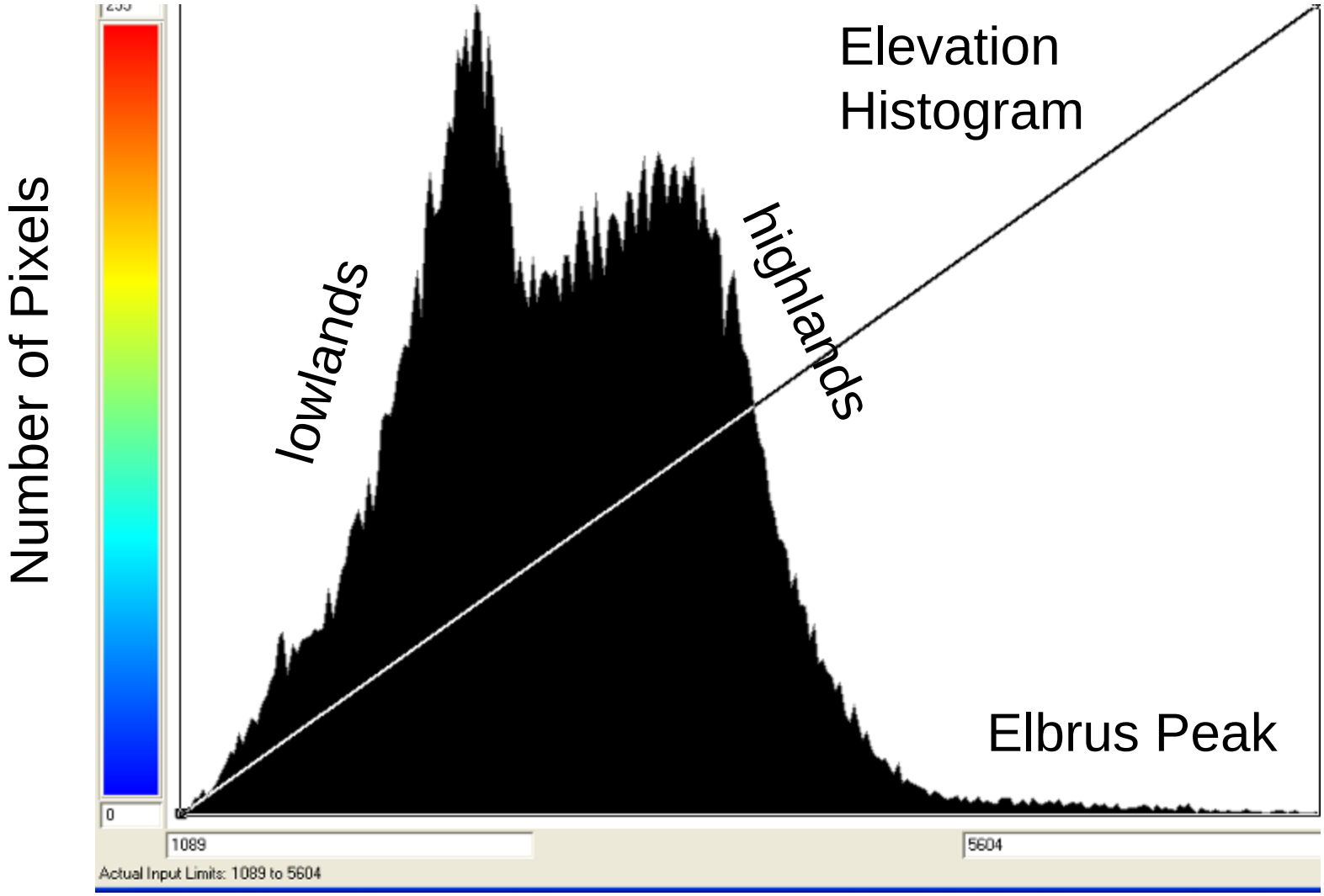
1. Rate of change of ground heat storage (or ice melting)
2. Net Radiation (short and long wave)
3. Turbulent heat flux to the atmosphere (sensible and latent heat)

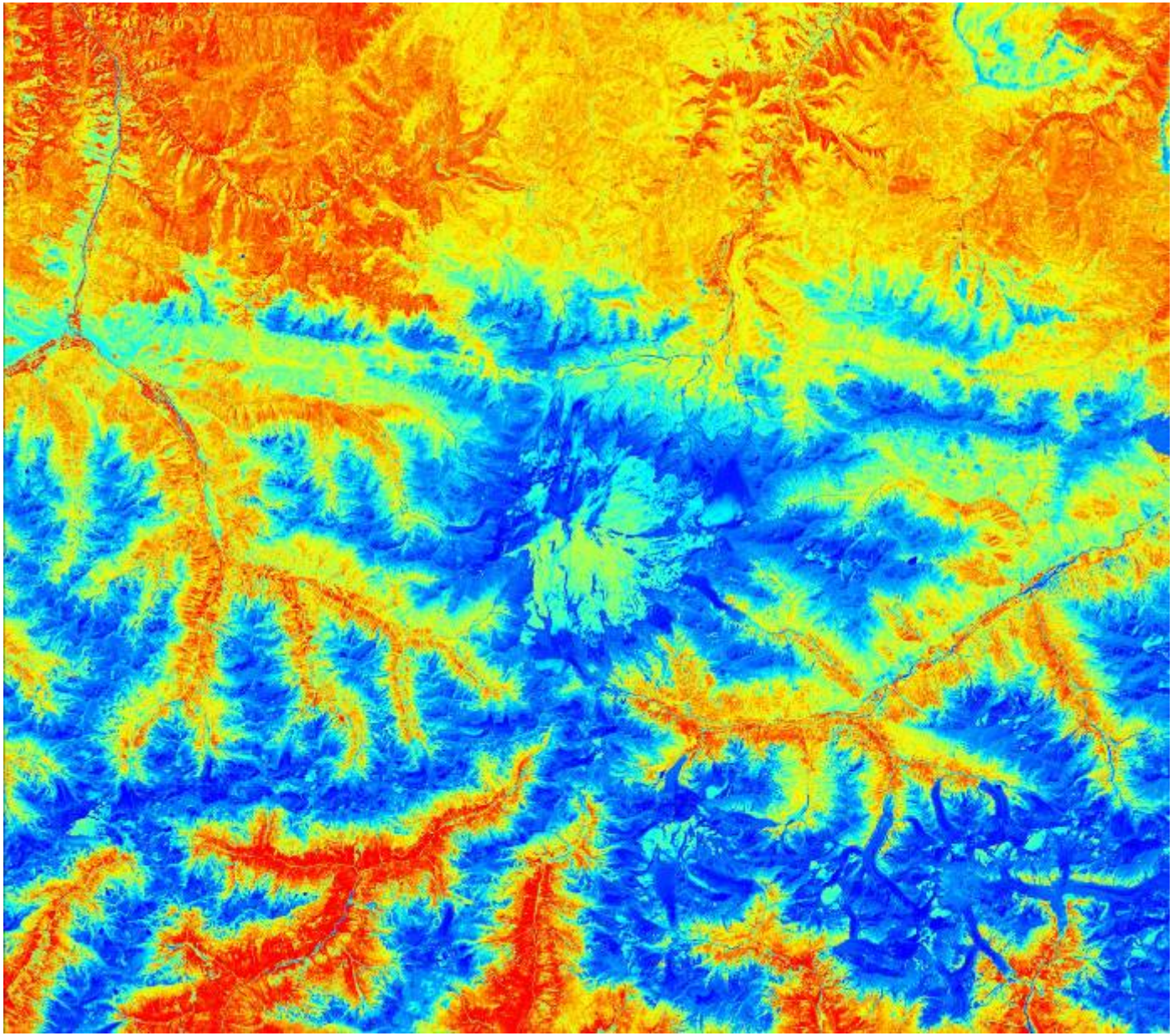
Data

1. Landsat ETM+ for 12 September 2000
   a) Land cover type (forest, snow, etc.)
   b) Surface temperature
   c) Albedo
2. Solar zenith and azimuthal angle
   a) Illumination angle
3. SRTM DEM
   a) Elevation
   b) Slope and aspect
4. Balloon Sounding from Rostov on Don (URRR)
   a) Temperature and RH as a function of altitude

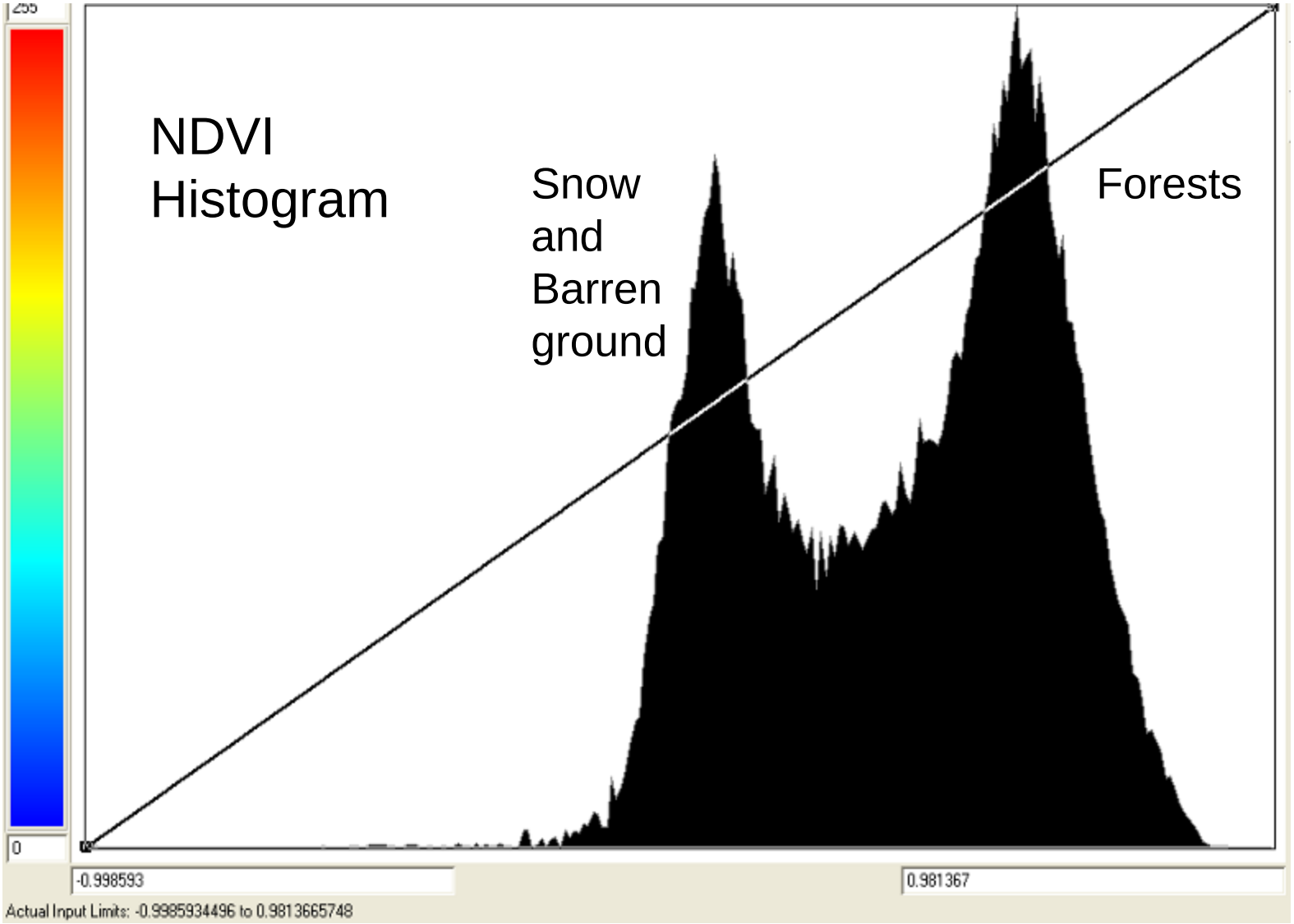


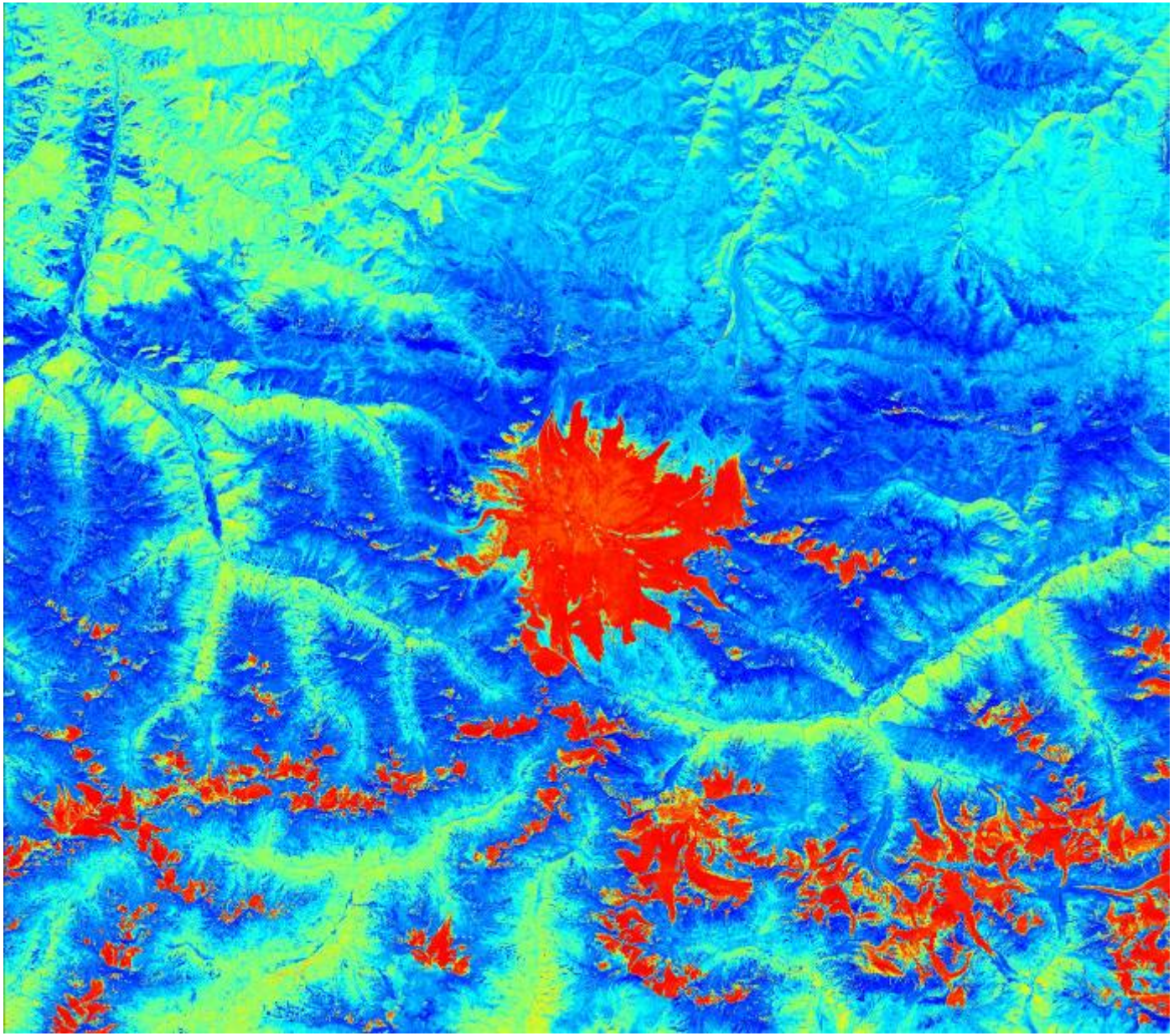
Elevation (peak ~ 5600 meters)


Number of Pixels
Elevation Histogram
lowlands
highlands
Elbrus Peak
0
1089
5604
Actual Input Limits: 1089 to 5604
Elevation

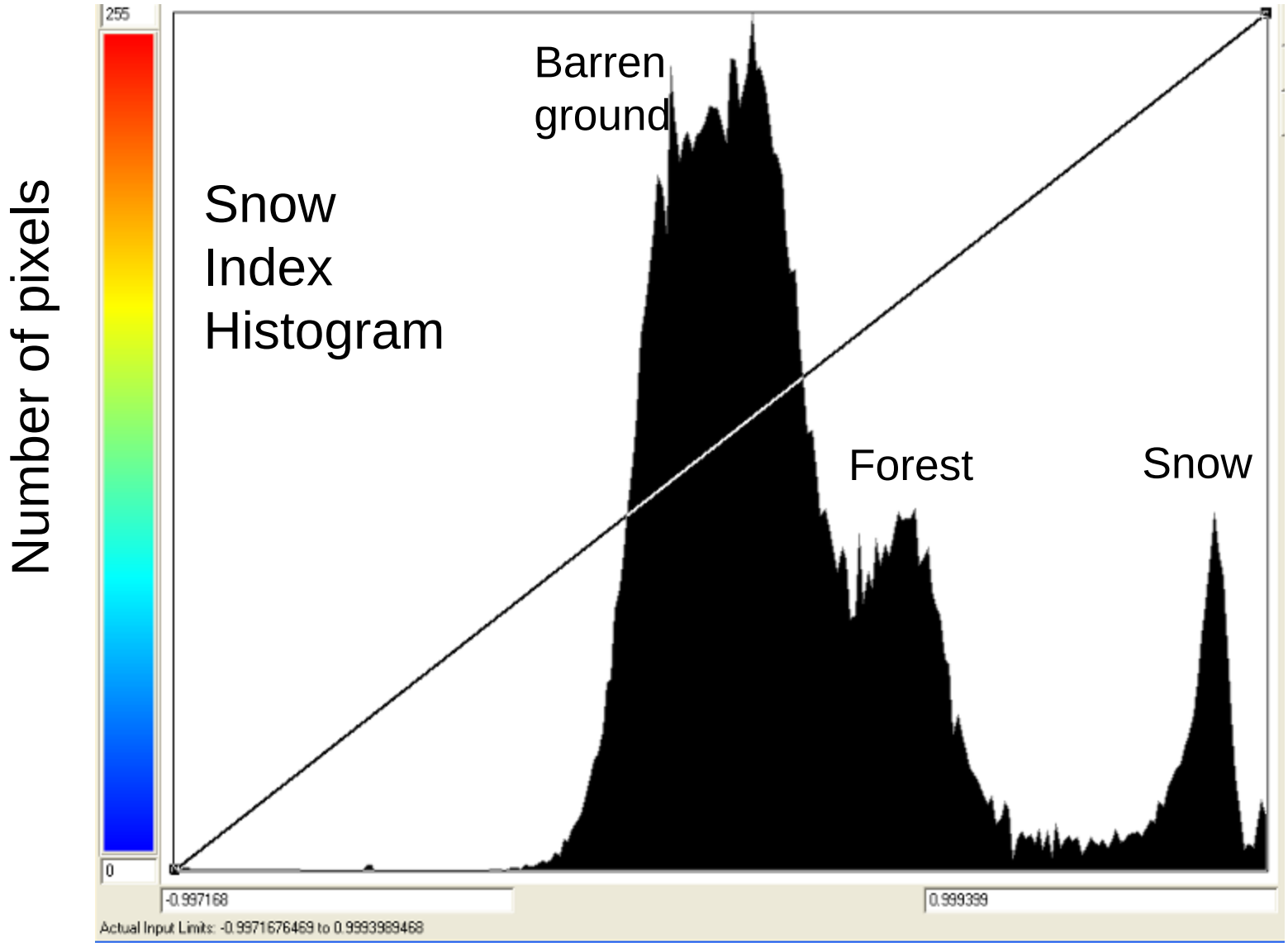


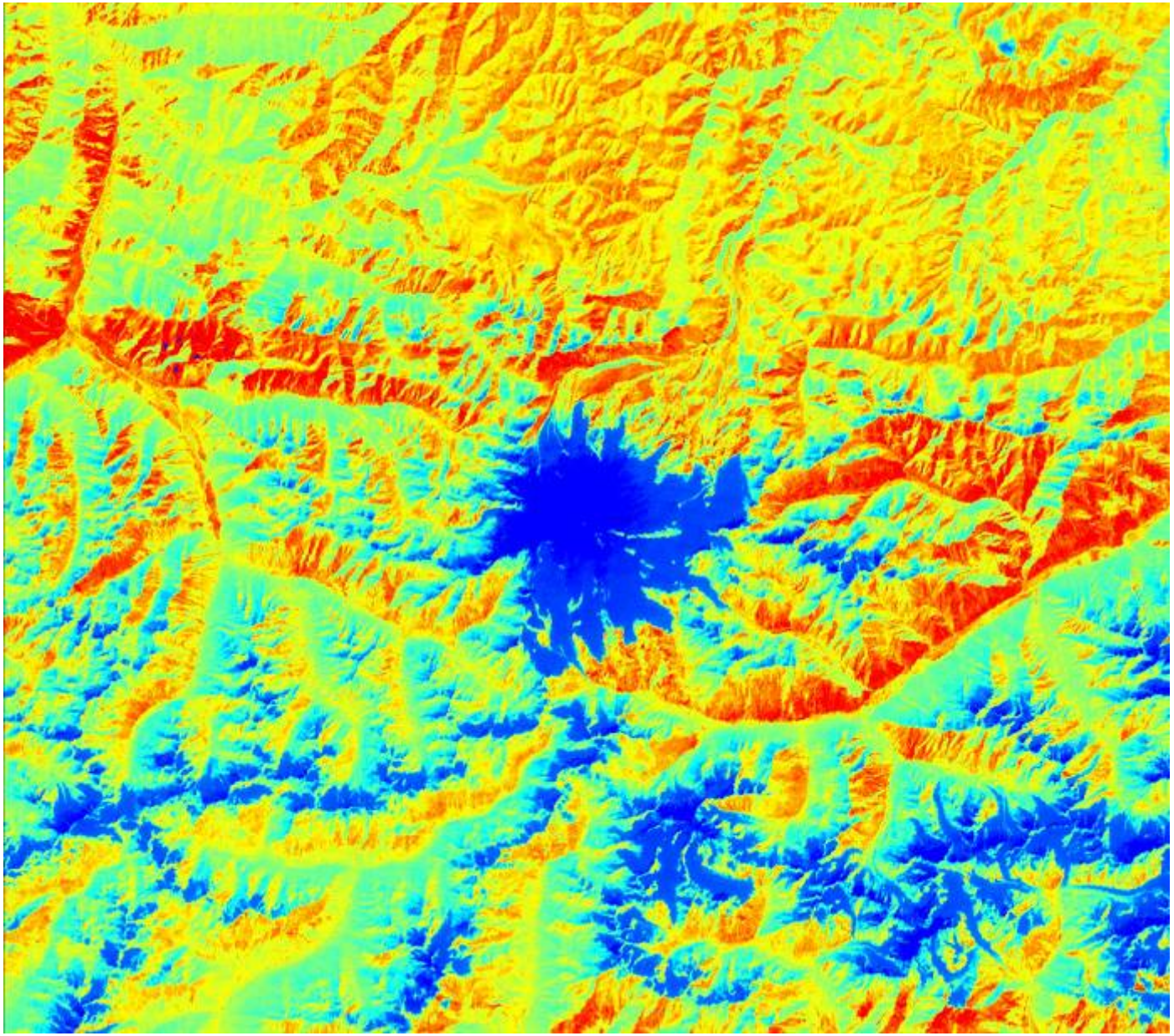
NDVI


NDVI
Histogram
Snow
and
Barren
ground
Forests
Number of Pixels
255
0
-0.998593
0.981367
Actual Input Limits: -0.9985934496 to 0.9813665748
NDVI

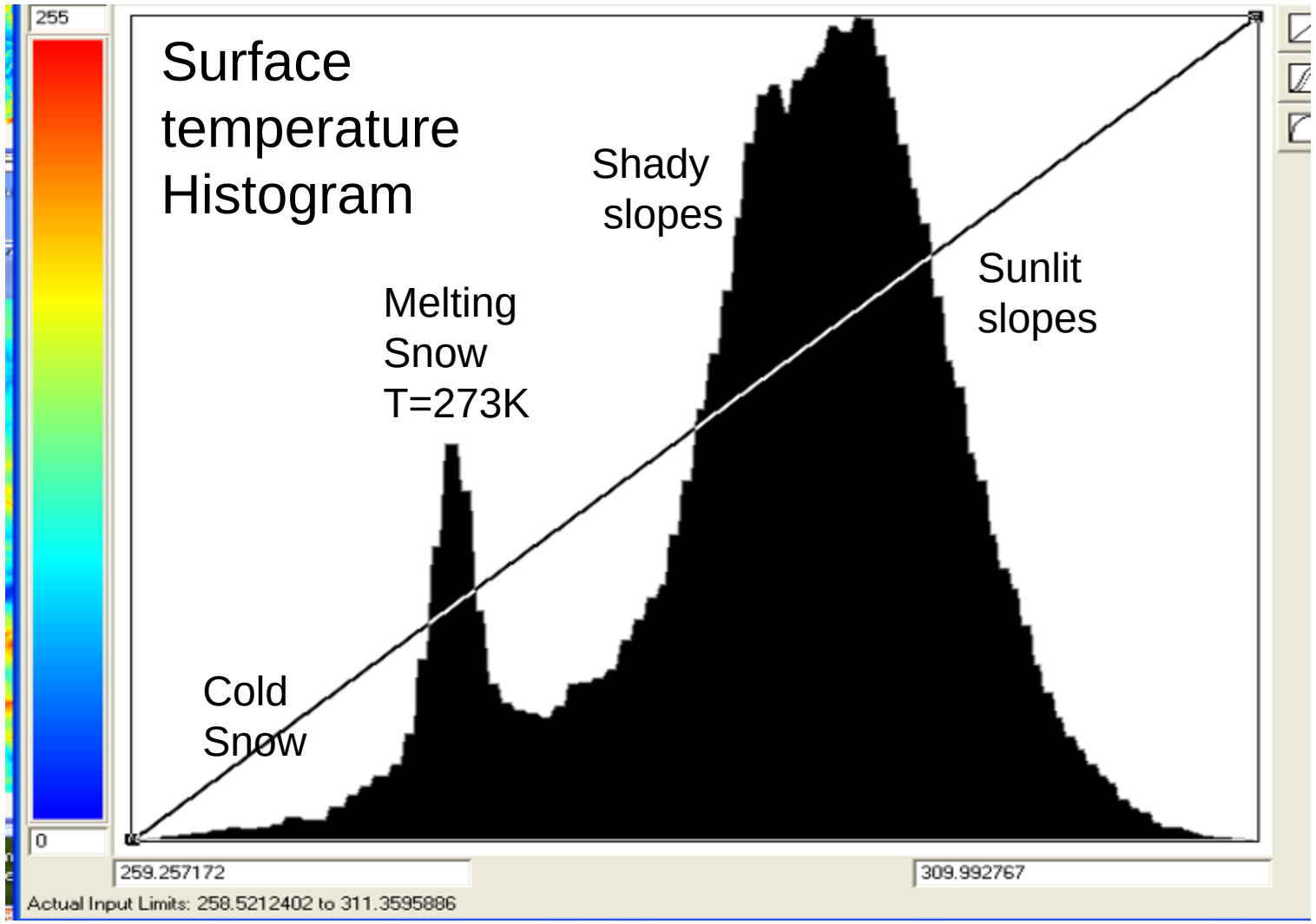


Snow Index


Number of pixels
255
0
Snow
Index
Histogram
Barren
ground
Forest
Snow
-0.997168
0.999399
Actual Input Limits: -0.9971676469 to 0.9993989468
Snow Index



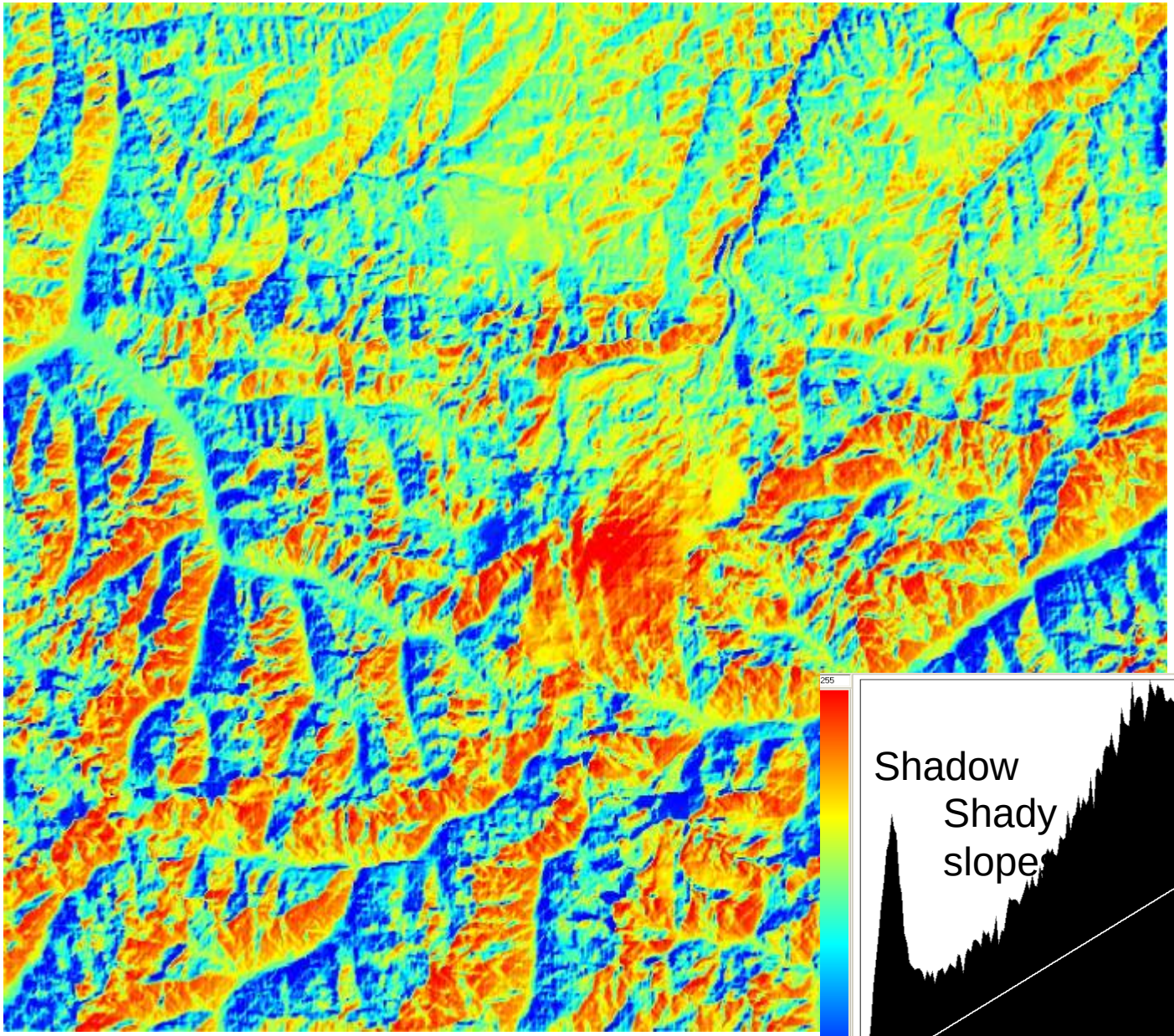
Surface Temperature

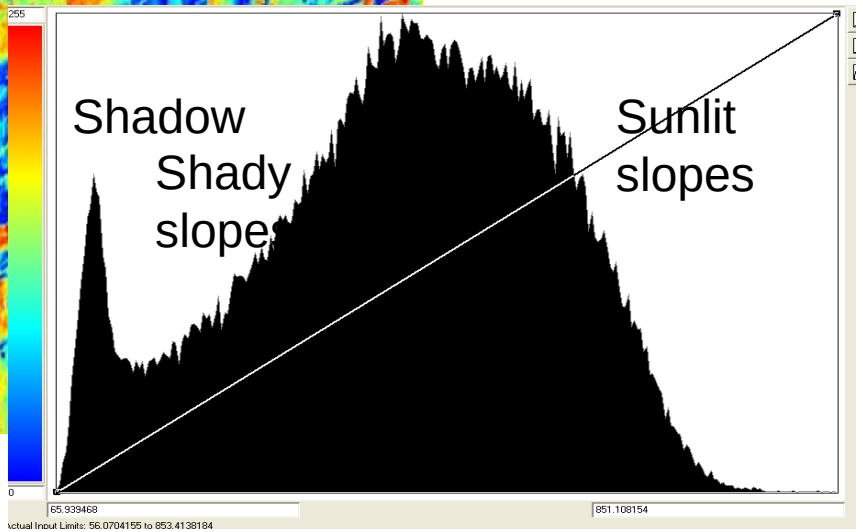

Number of pixels
255
0
Surface
temperature
Histogram
Shady
slopes
Sunlit
slopes
Melting
Snow
T=273K
Cold
Snow
259.257172
309.992767
Actual Input Limits: 258.5212402 to 311.3595886
Surface Temperature (K)

Solar Analyst

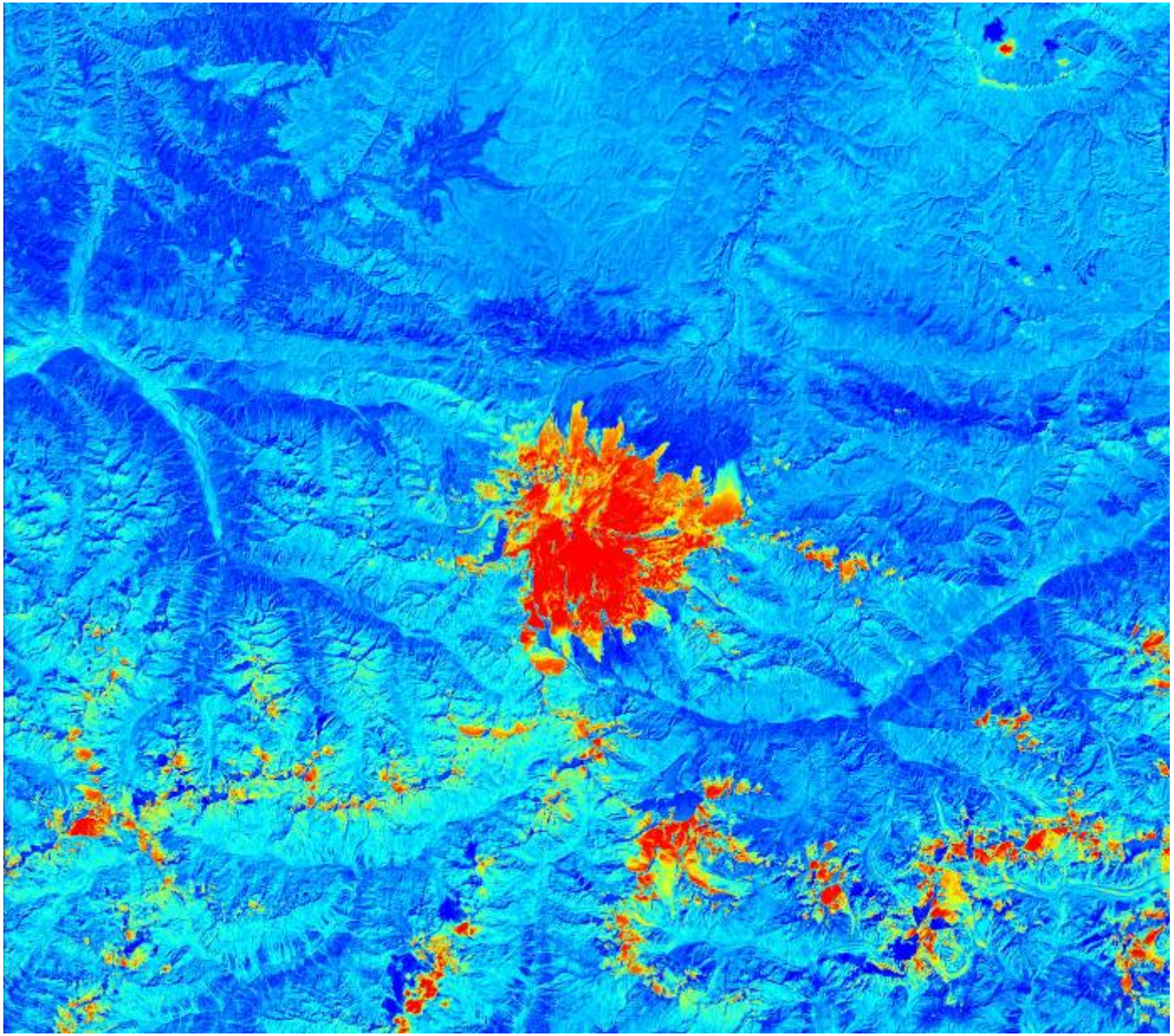
- Plug-in for ERDAS Imagine
- Uses sun angle and terrain shape to compute incident radiation for each pixel
- Includes direct and indirect short wave radiation
- Requires user-chosen absorption and scattering coefficient values.

Incident Radiation from Solar Analyst

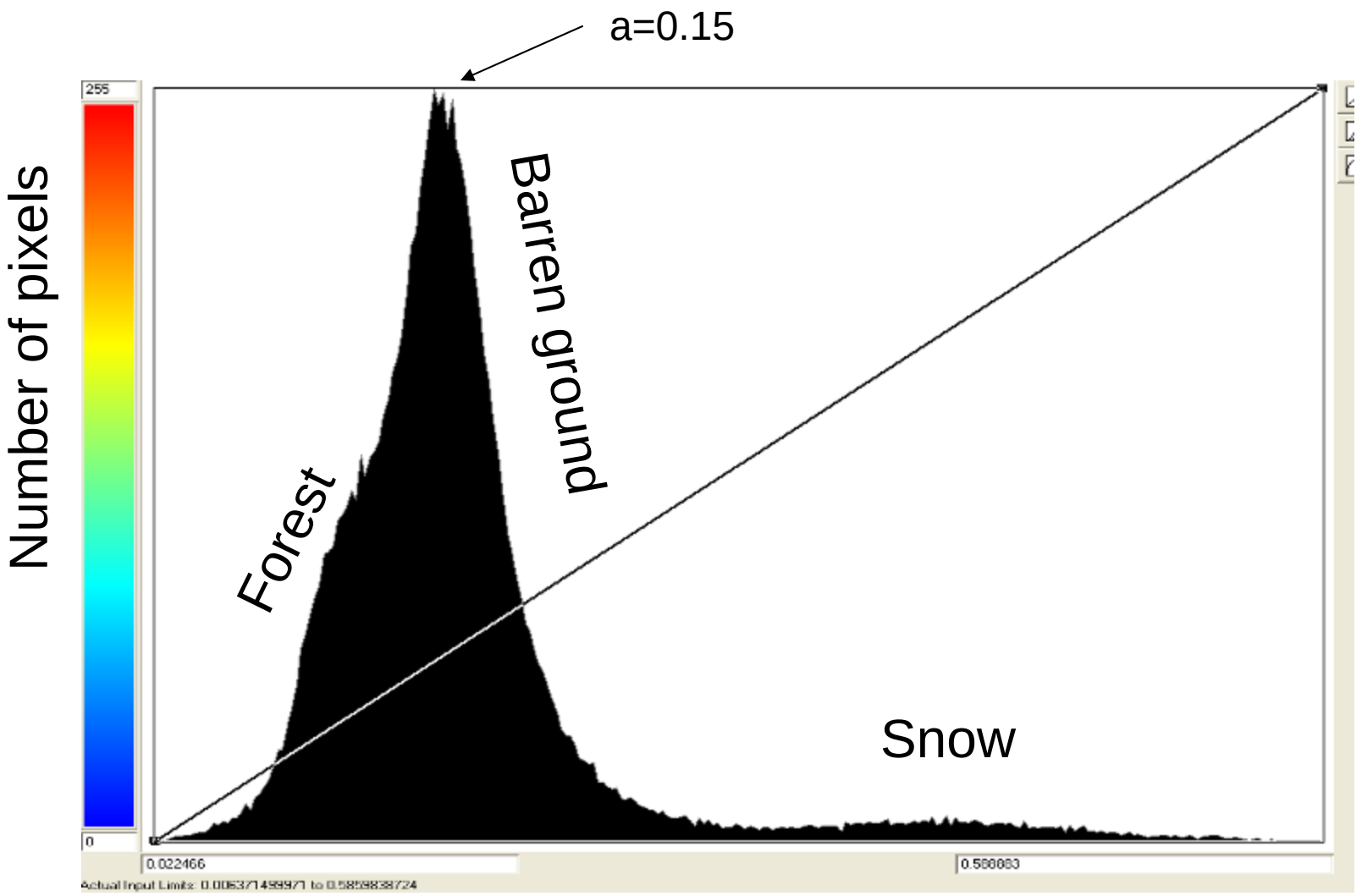


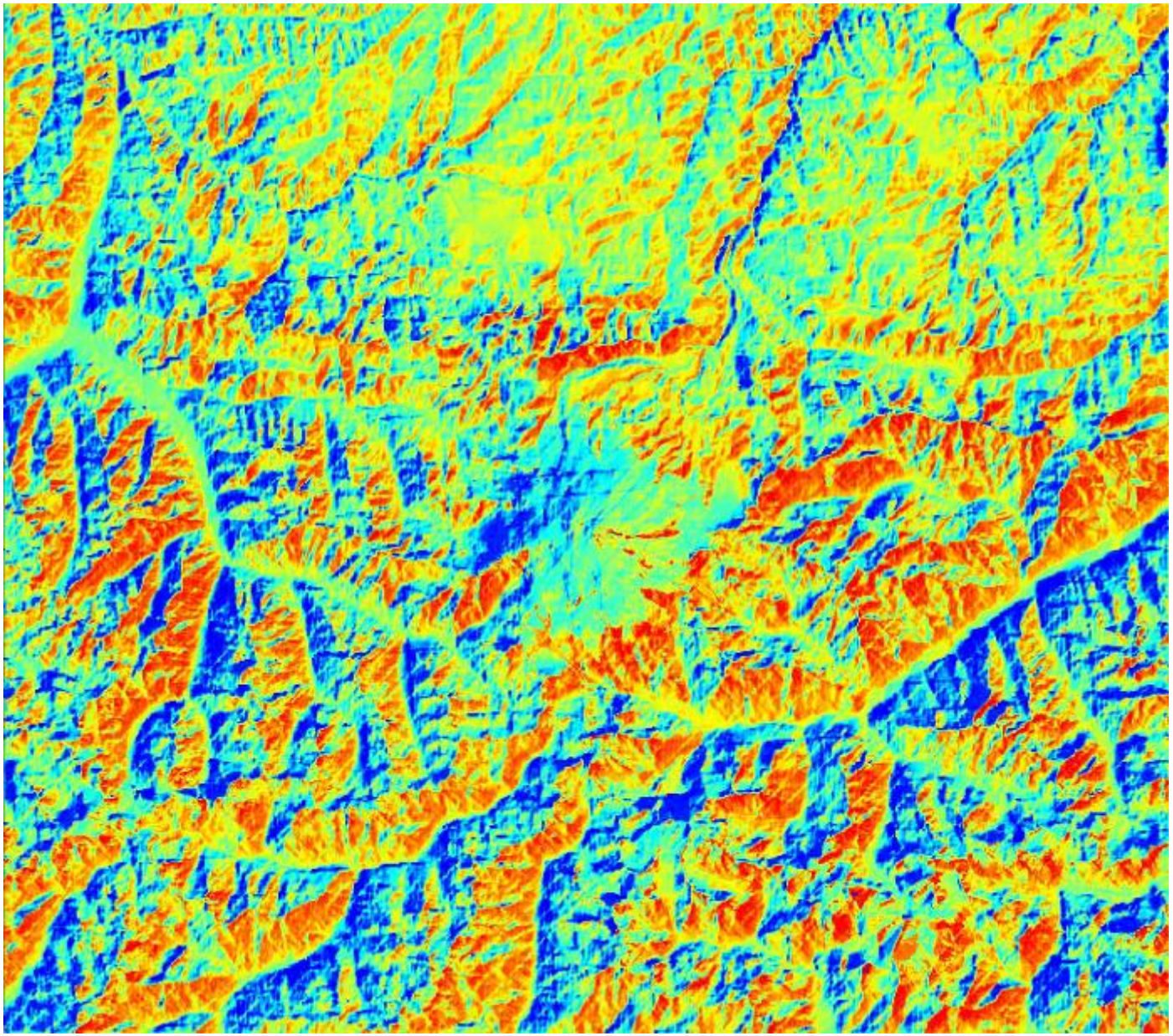


Histogram

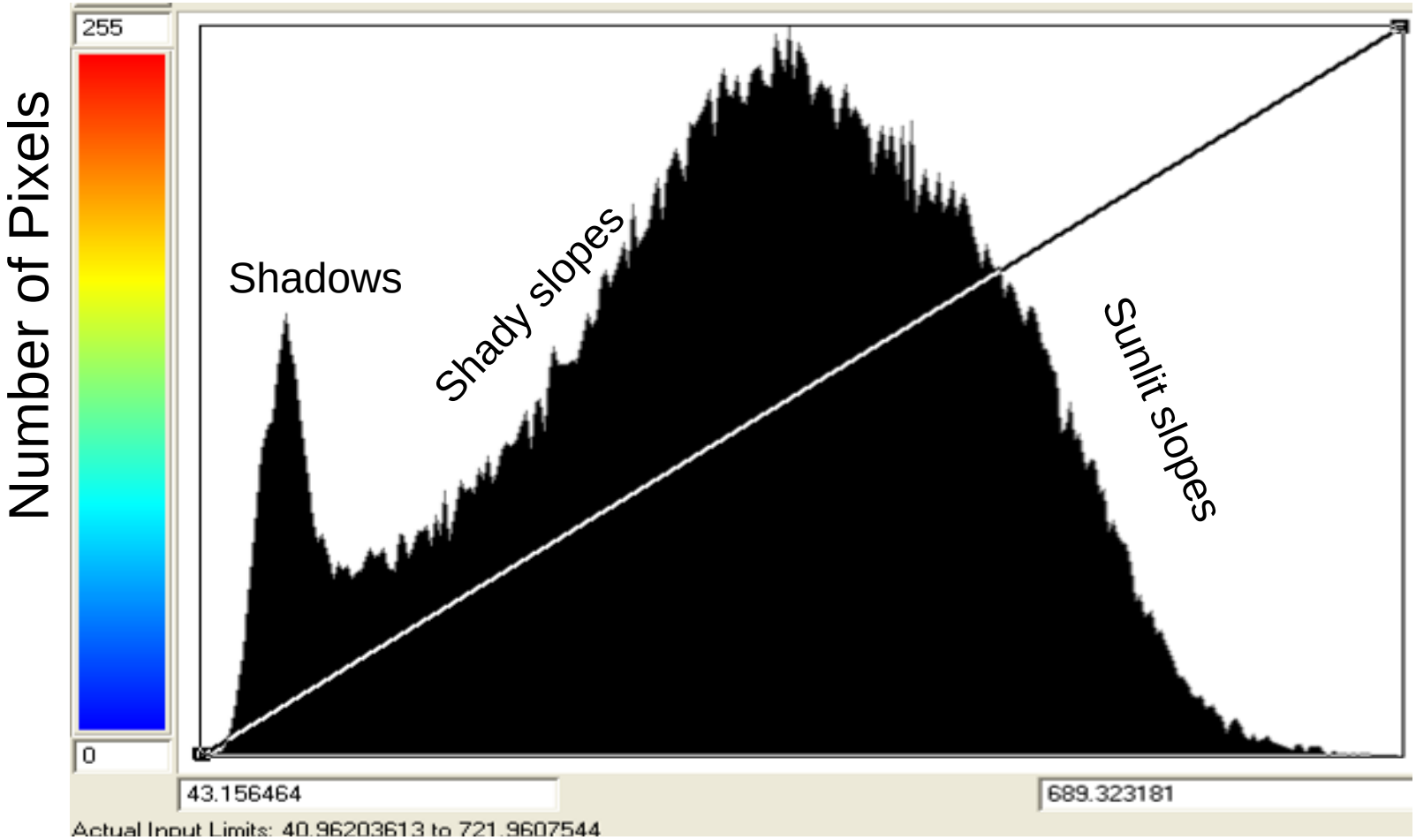


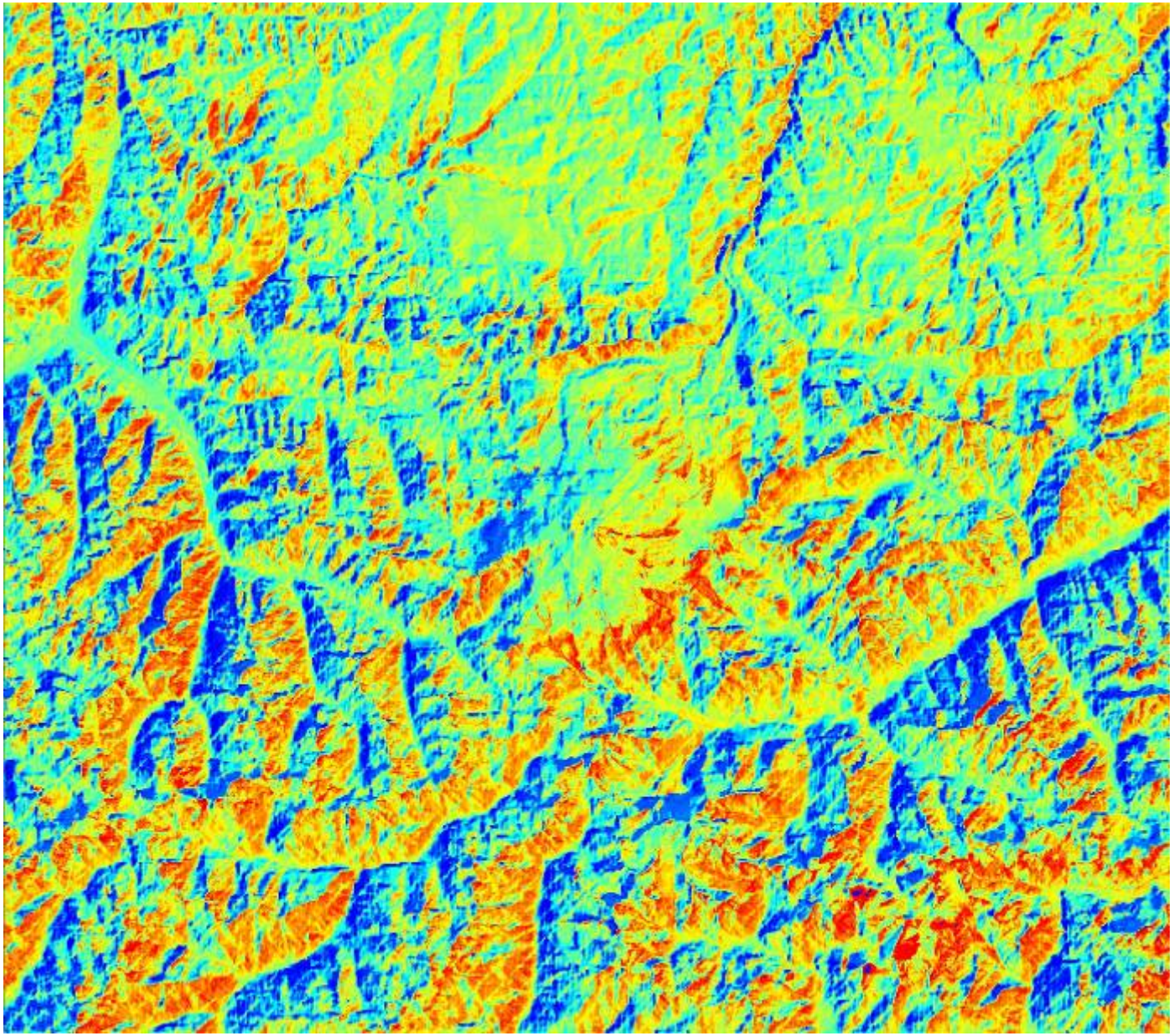
Corrected Albedo (Mod 4 using SAT)


a=0.15
Number of pixels
255
0
Barren ground
Forest
Snow
0.022466
0.588083
Actual Input Limits: 0.00637149997 to 0.5859838724
Albedo



Absorbed Solar Radiation (W/m2)


Number of Pixels
255
0
Shadows
Shady slopes
Sunlit slopes
43.156464
689.323181
Actual Input Limits: 40.96203613 to 721.9607544
Absorbed Solar Radiation (W/m2)



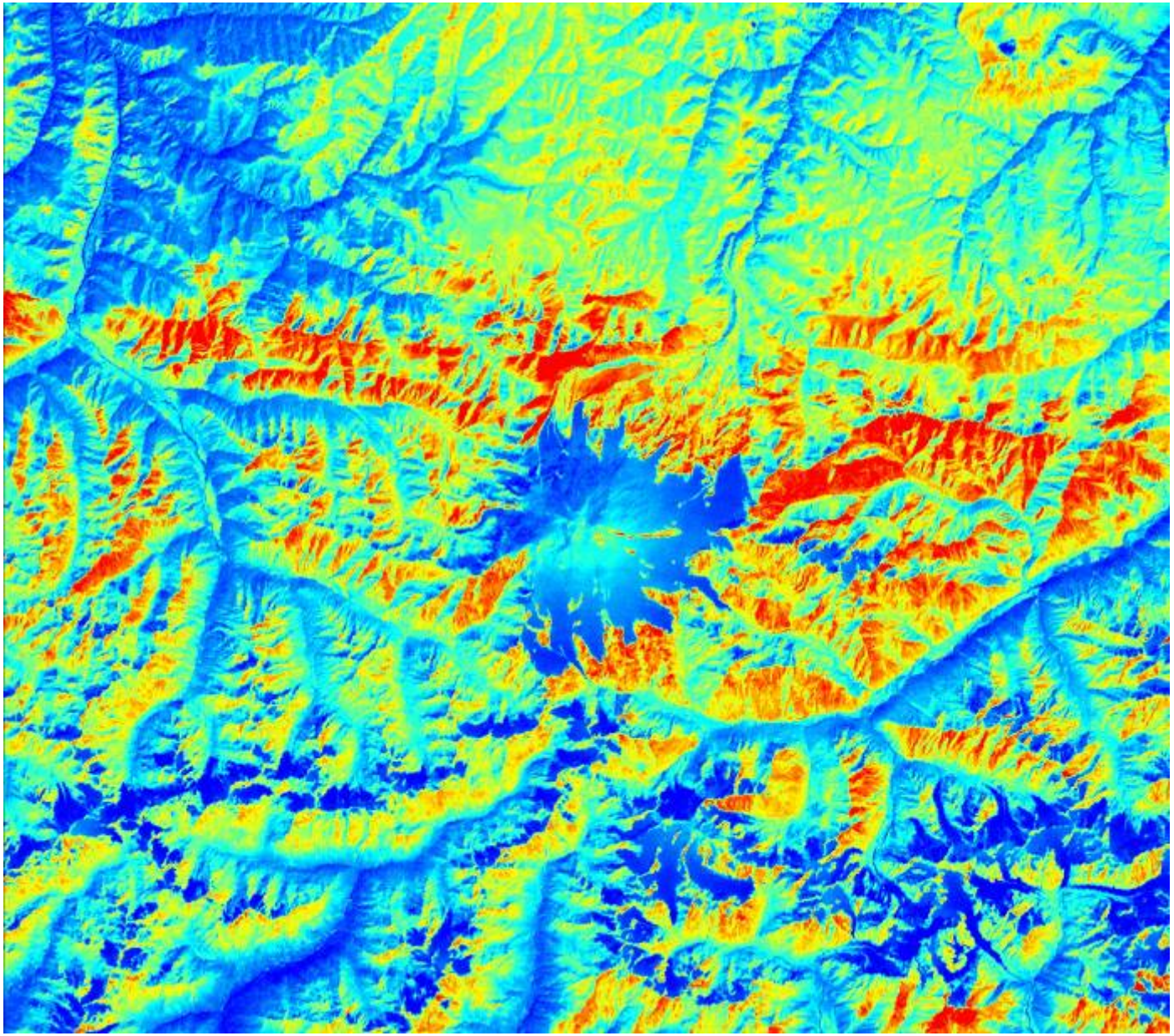
Net Radiation (W/m2)

Sensible heat flux

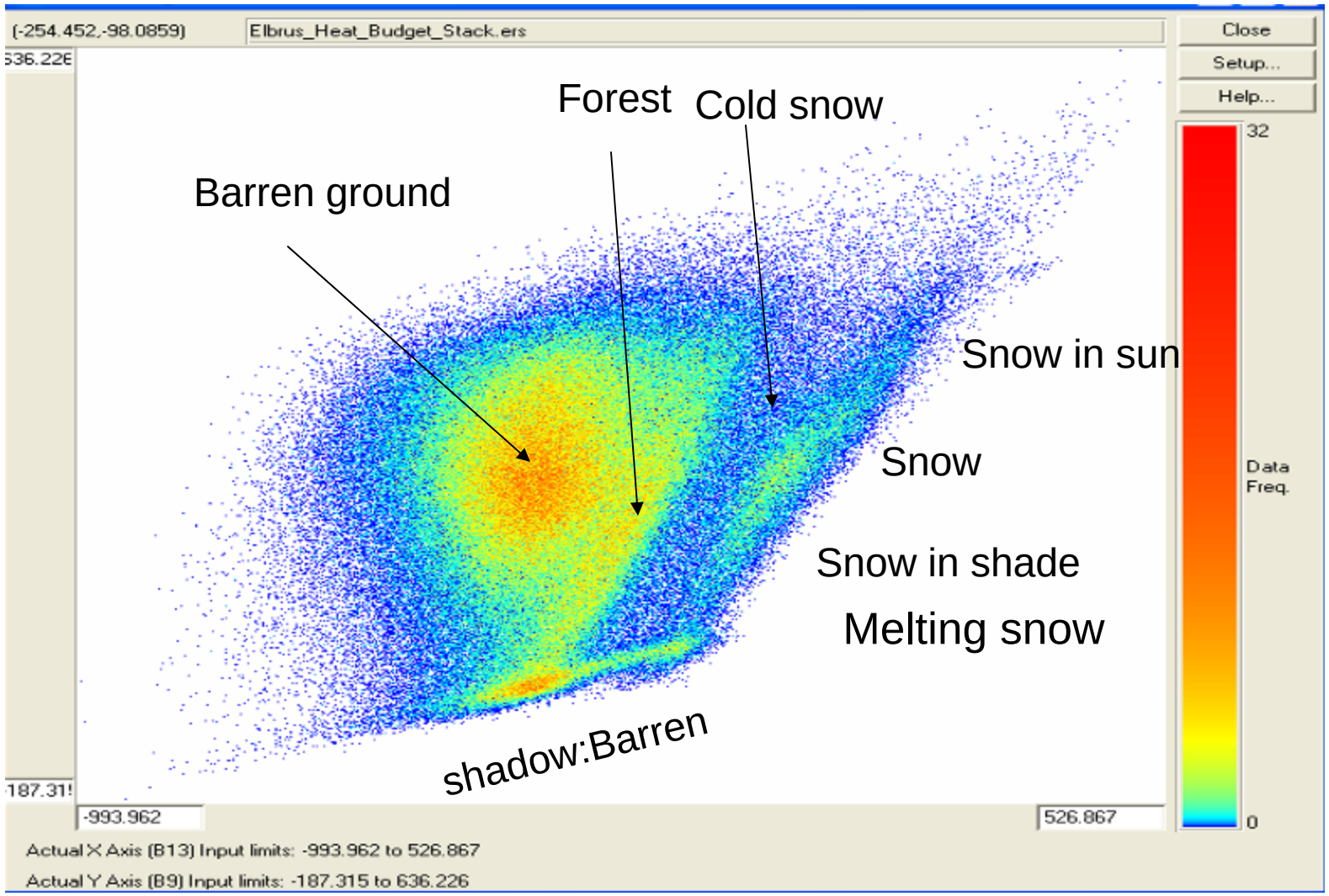
$$H = \rho C_P C_{DH} U (T_S - T_A)$$

Term 1 2 3 4 5 6 7

1. Sensible heat flux (W/m2)
2. Air density
3. Heat Capacity at constant pressure for air
4. Exchange coefficient (empirical)
5. Wind speed
6. Surface temperature (from satellite)
7. Air temperature T(z) (from sounding)



Sensible Heat Flux (W/m2)



Net Radiation (W/m2)

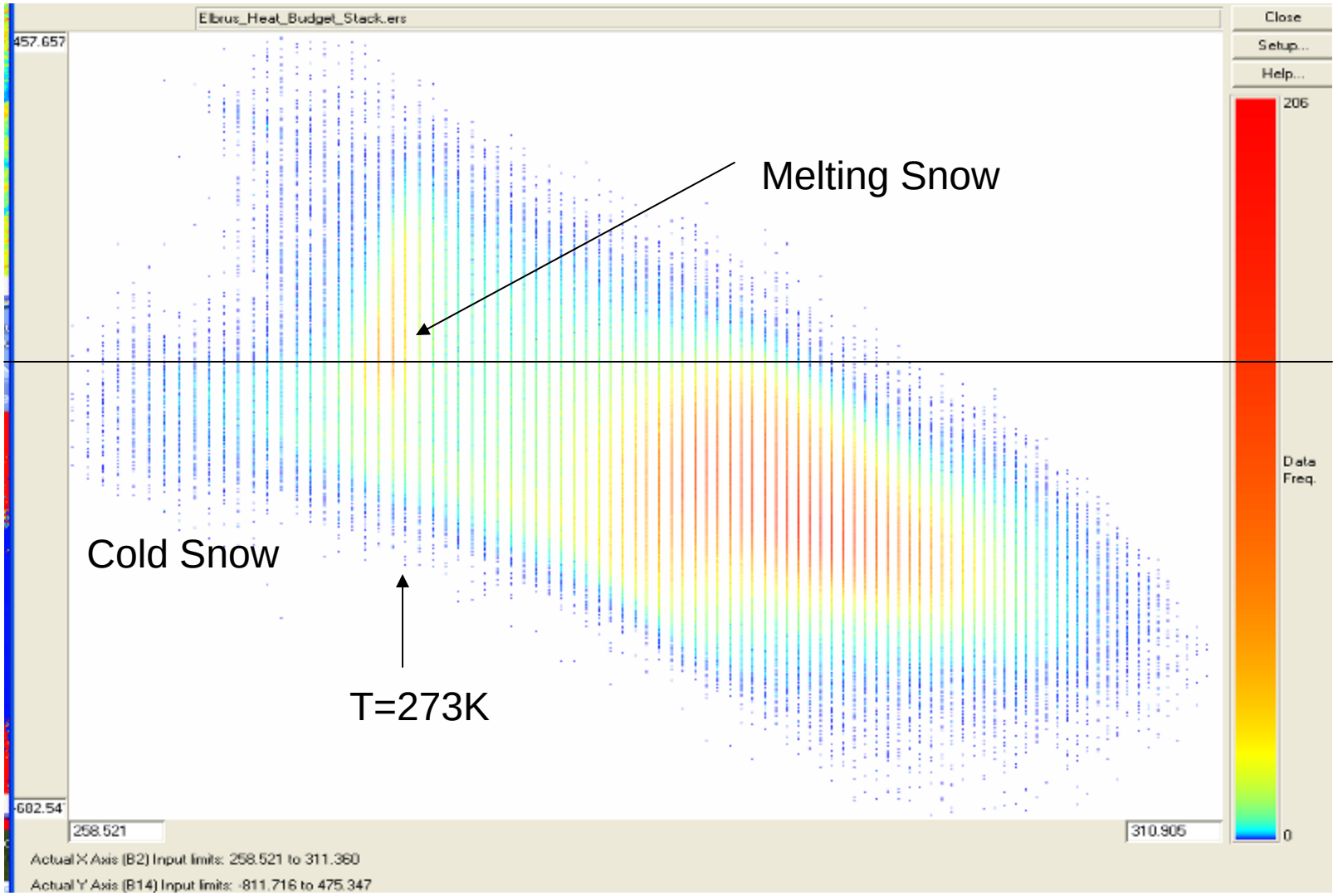
Imbalance (W/m2)

Conclusions

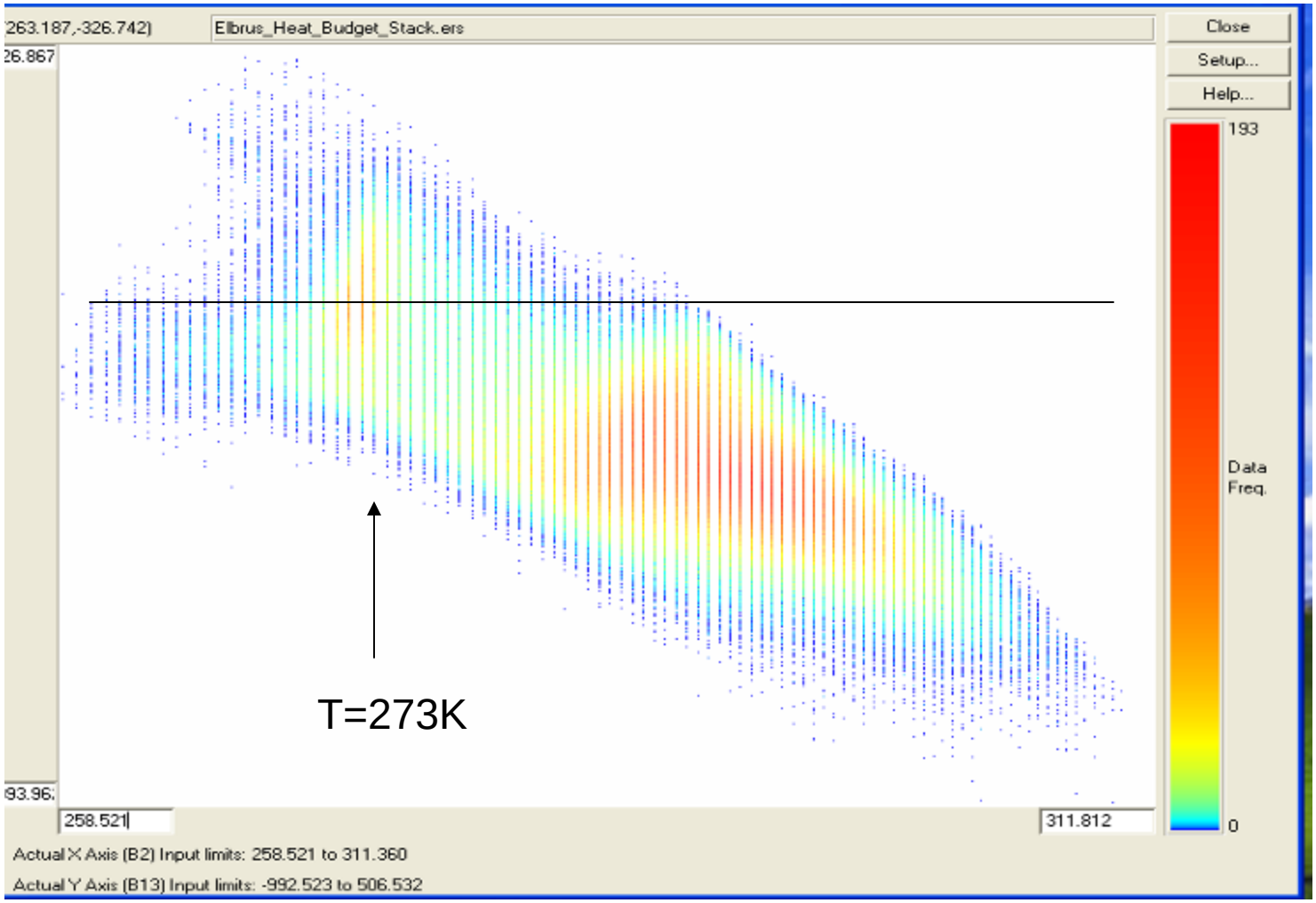
- Several heat budget types are found in the Elbrus region
  - Forest (small albedo, large latent heat)
  - Barren ground (small latent heat)
  - Melting snow (T=0C; heat flux imbalance)
  - Cold snow (large albedo)
- Each land cover type has a *sunny* and *shady* heat budget type

Significant Errors

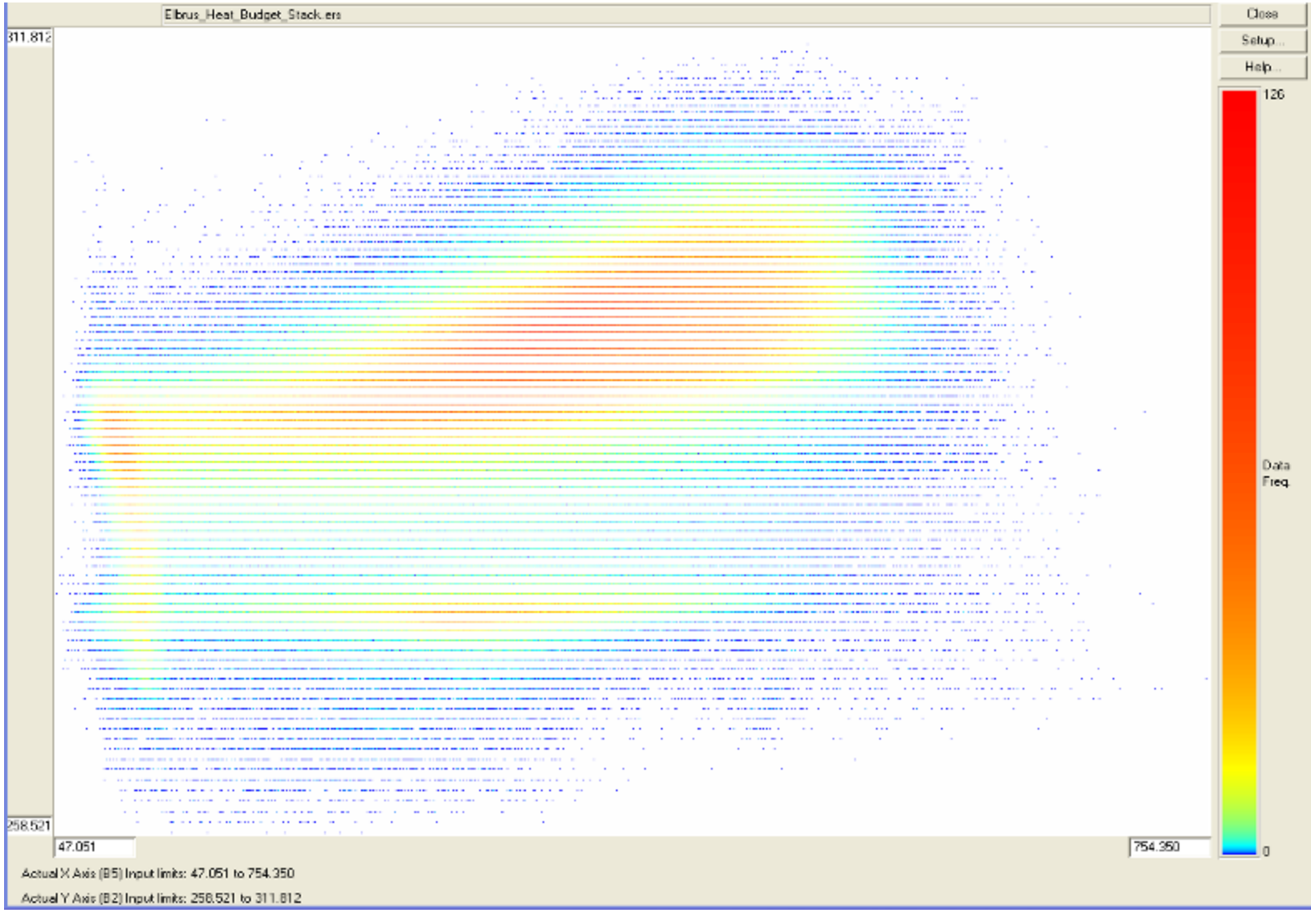
- Uncertain absorption and scattering parameters in Solar Analyst
- Used a simple albedo correction based on SAT
- Assumed single sounding gave air temperature T(z) everywhere
- Sensible heat estimation uses constant wind speed and roughness
- Poor latent heat estimation



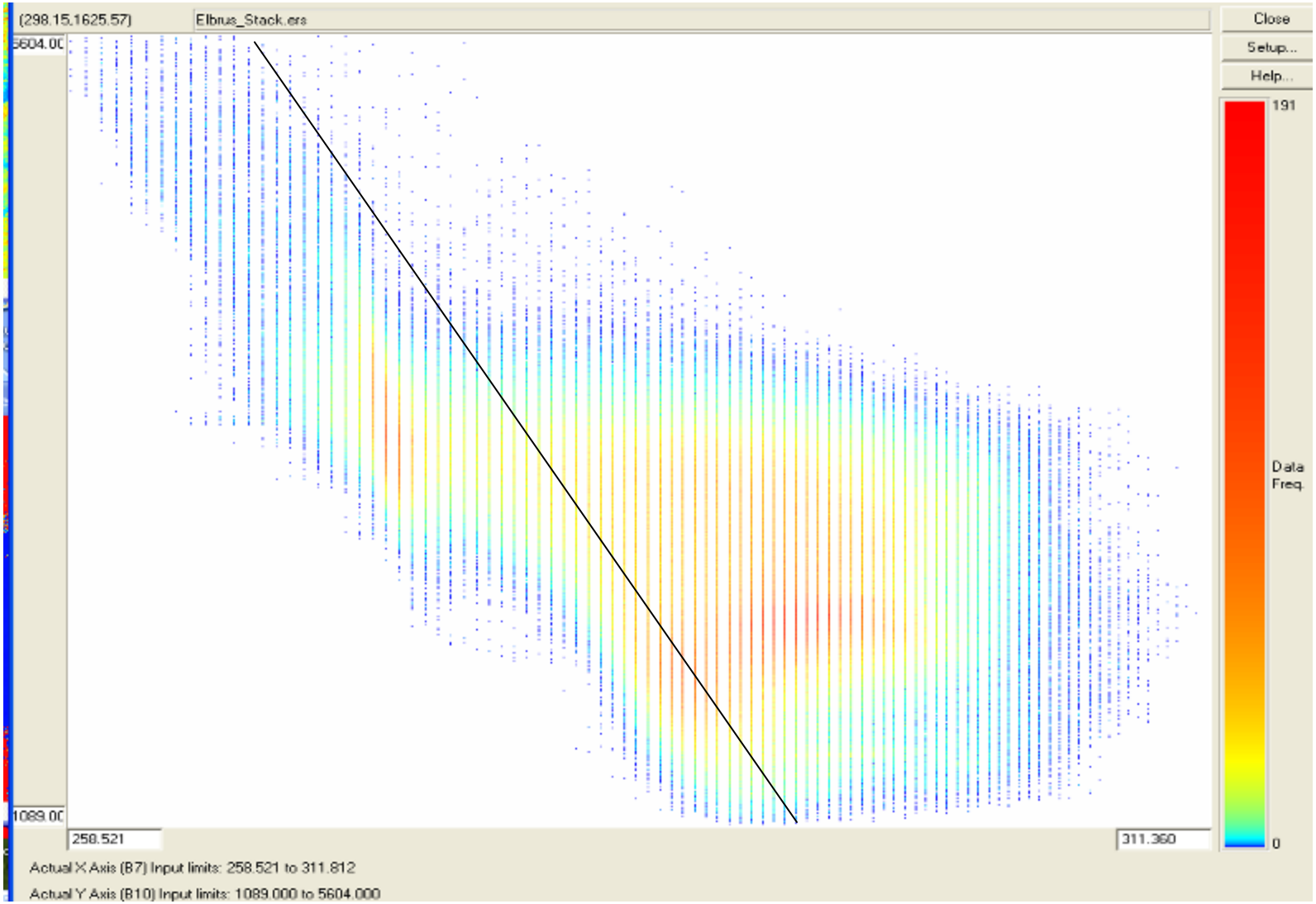
Surface temperature versus heat Imbalance



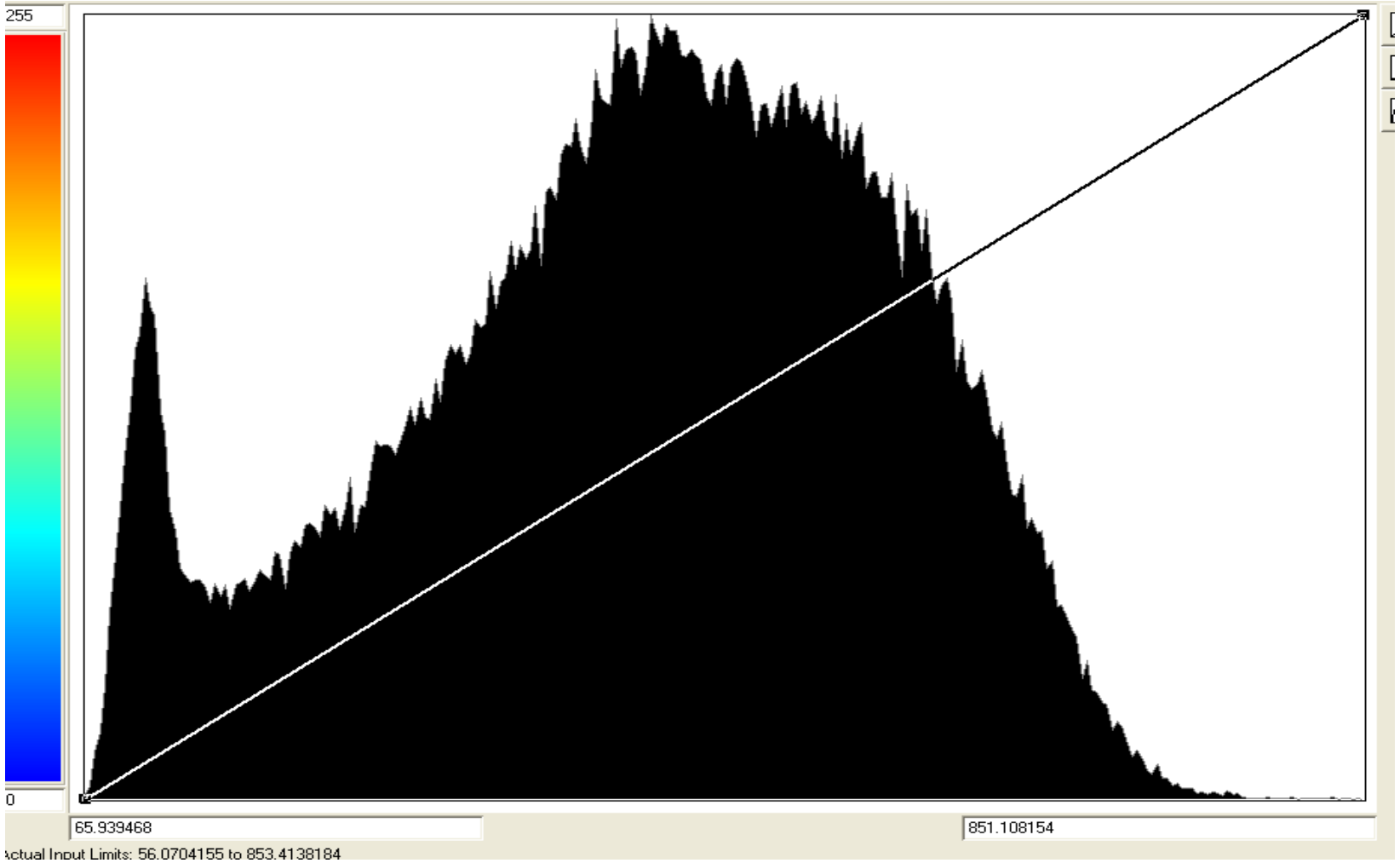
Surface Temperature (K) versus Basic Balance (Mod 4)



Absorbed Solar versus Surface temperature

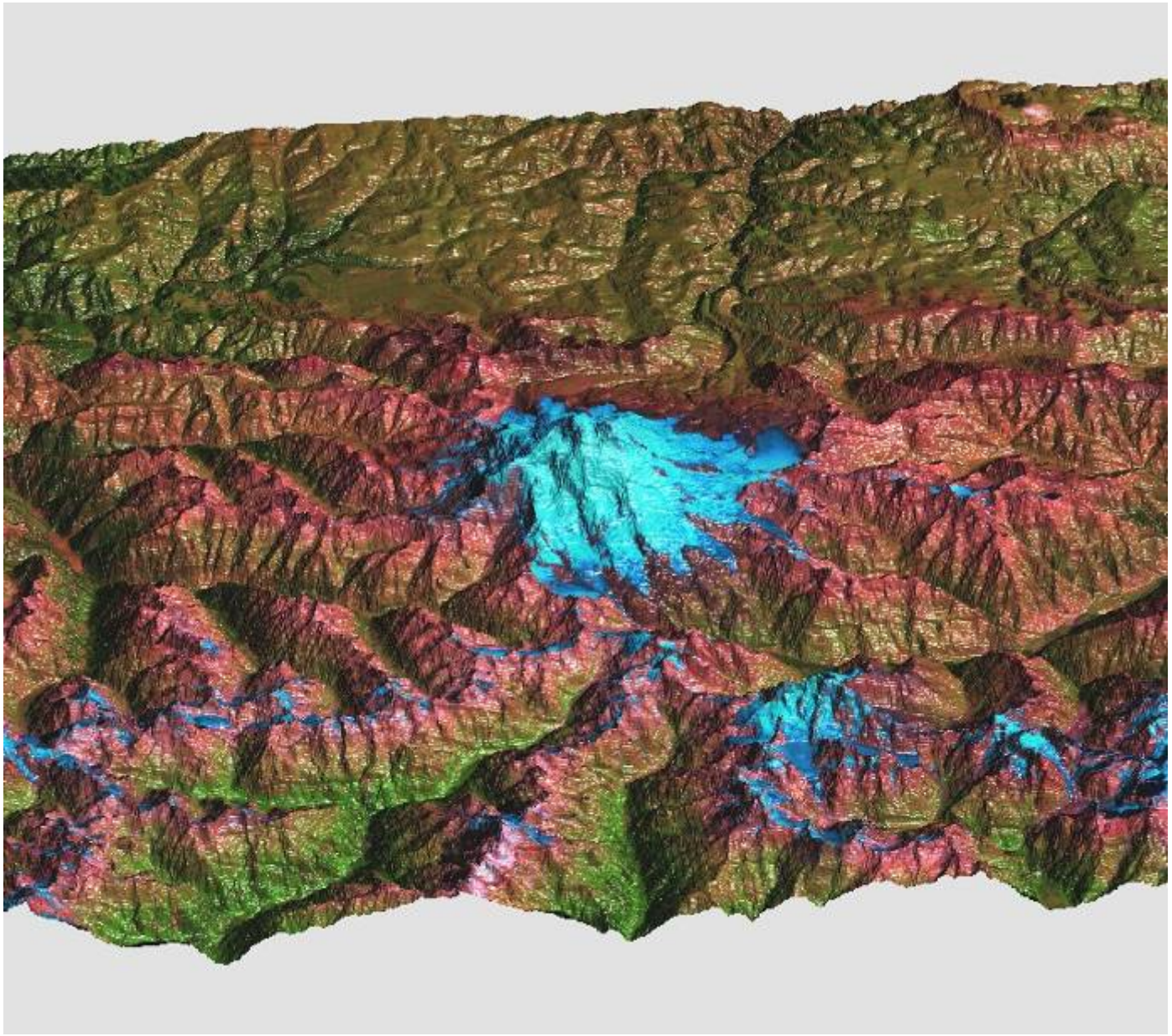


Surface Temperature (K) versus Elevation (m)



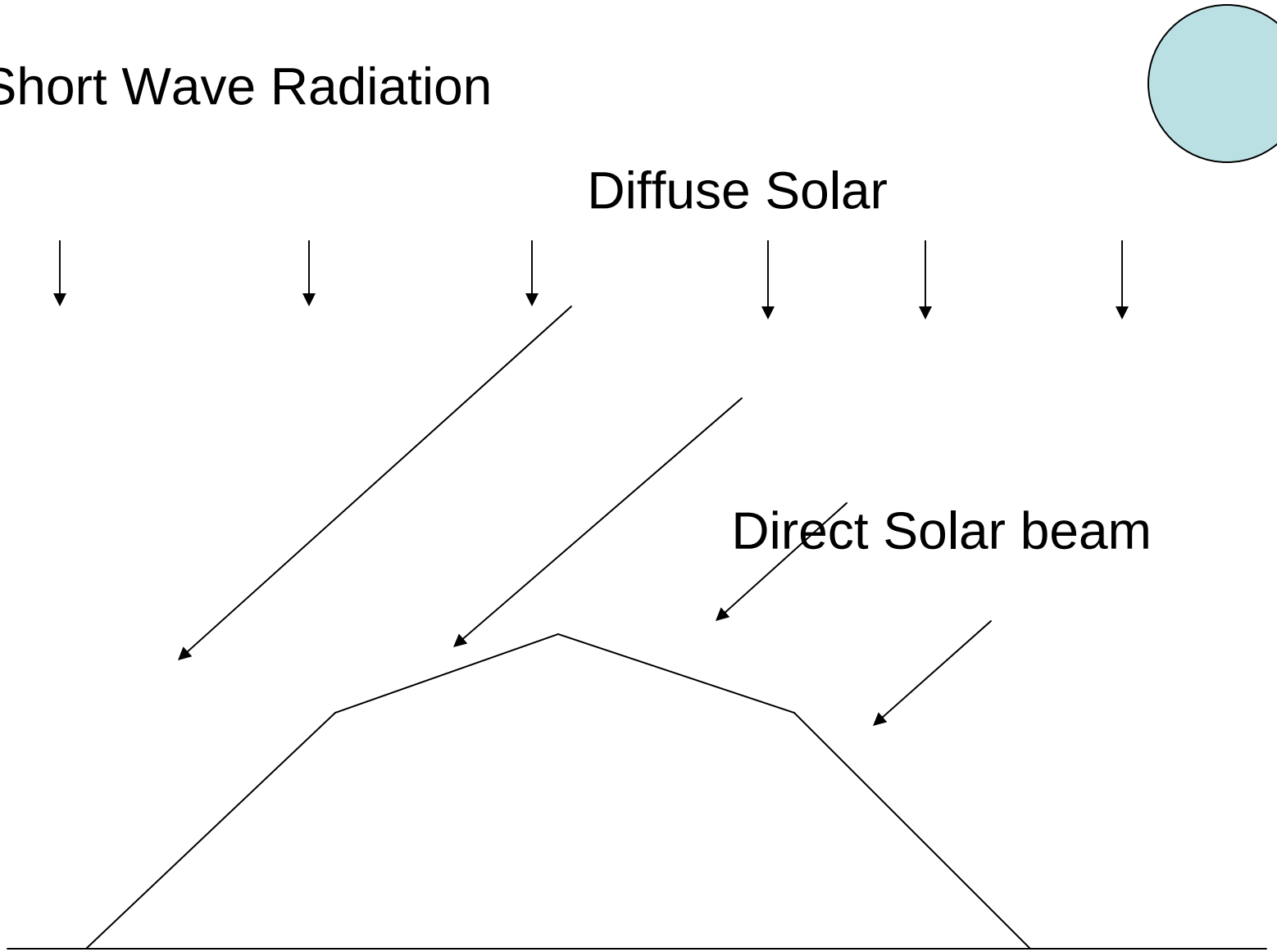
Incident Radiation Histogram

Incident Radiation from Solar Analyst (W/m2)

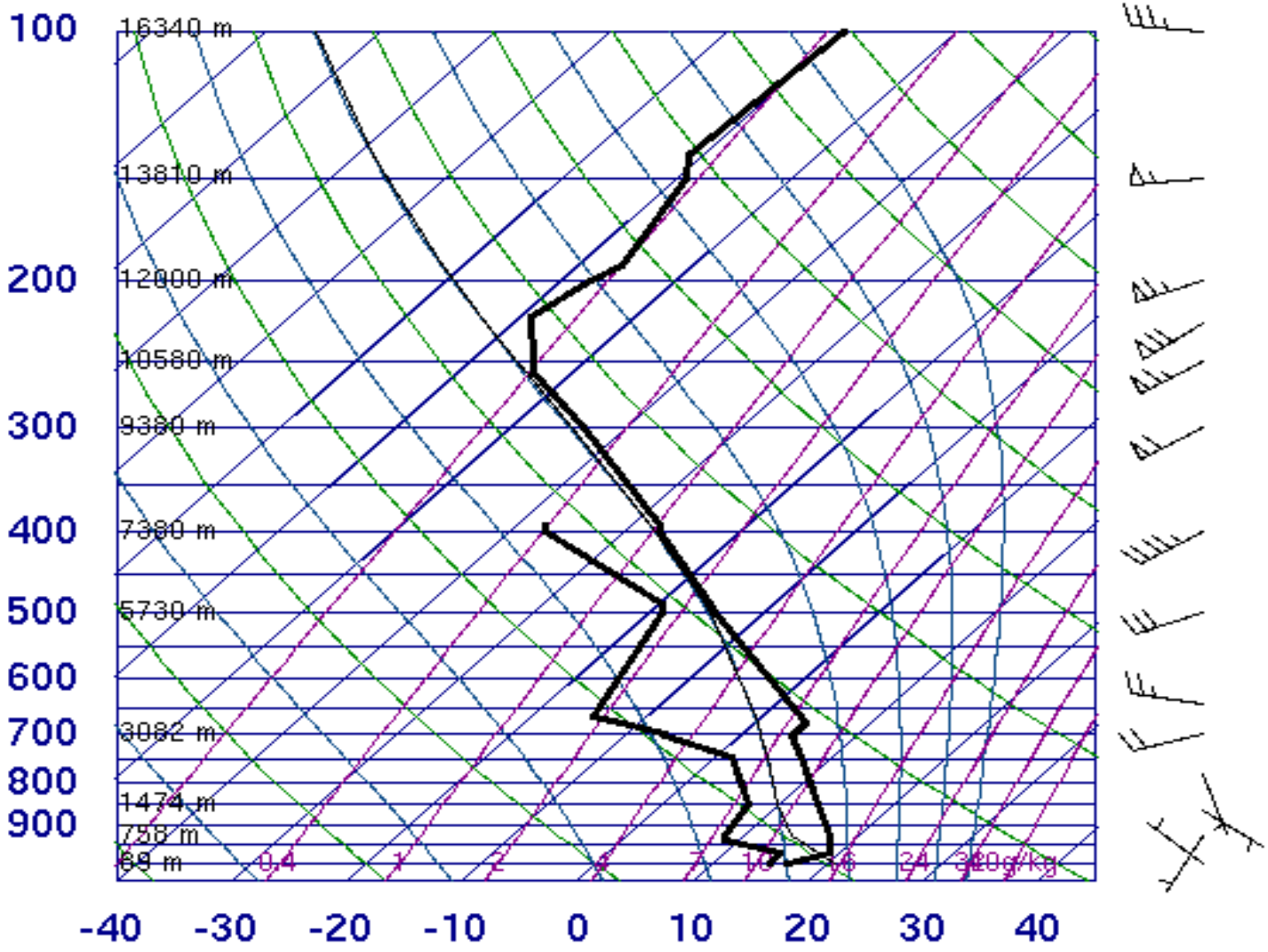


Landsat RGB-742

Short Wave Radiation



34731 URRR Rostov-Na-Donu

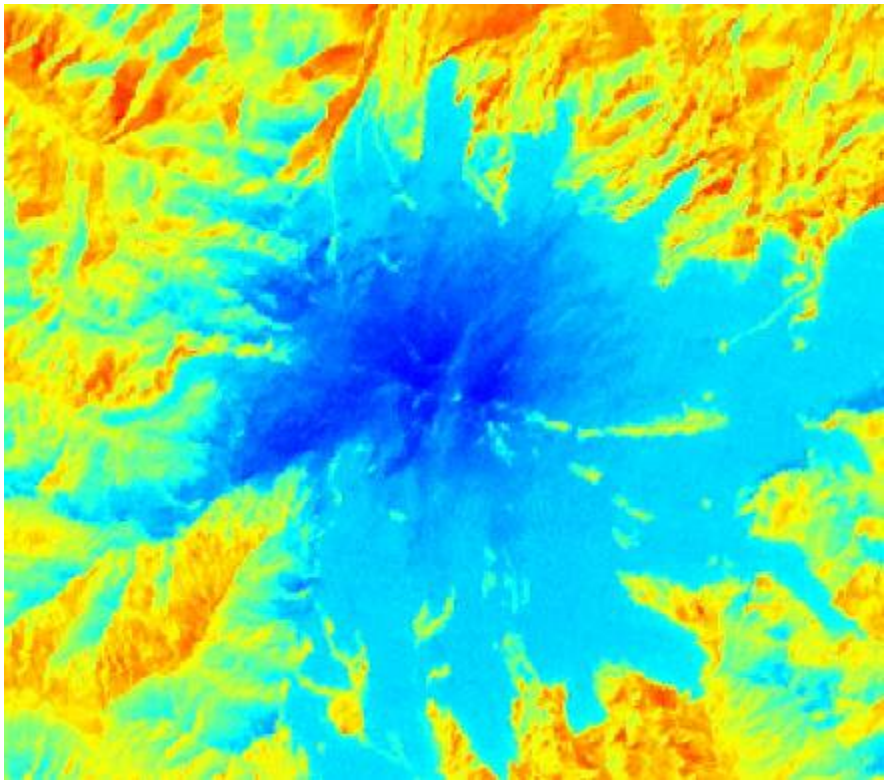


SLAT	47.25
SLON	39.81
SELV	78.00
SHOW	0.53
LIFT	0.39
LFTV	0.28
SWET	139.5
KINX	24.10
CTOT	21.70
VTOT	27.70
TOTL	49.40
CAPE	0.00
CAPV	0.00
CINS	0.00
CINV	0.00
EQLV	-9999
EQTV	-9999
LFCT	-9999
LFCV	-9999
BRCH	0.00
BRCV	0.00
LCLT	285.9
LCLP	910.7
MLTH	293.7
MLMR	10.34
THCK	5641.
PWAT	27.56

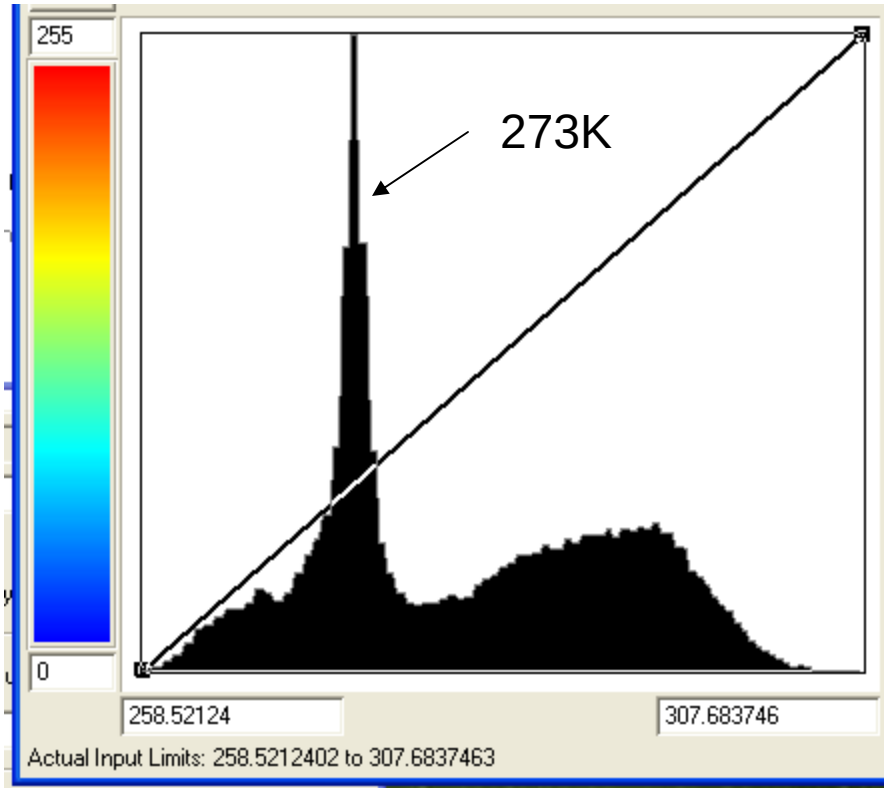
00Z 12 Sep 2000

University of Wyoming

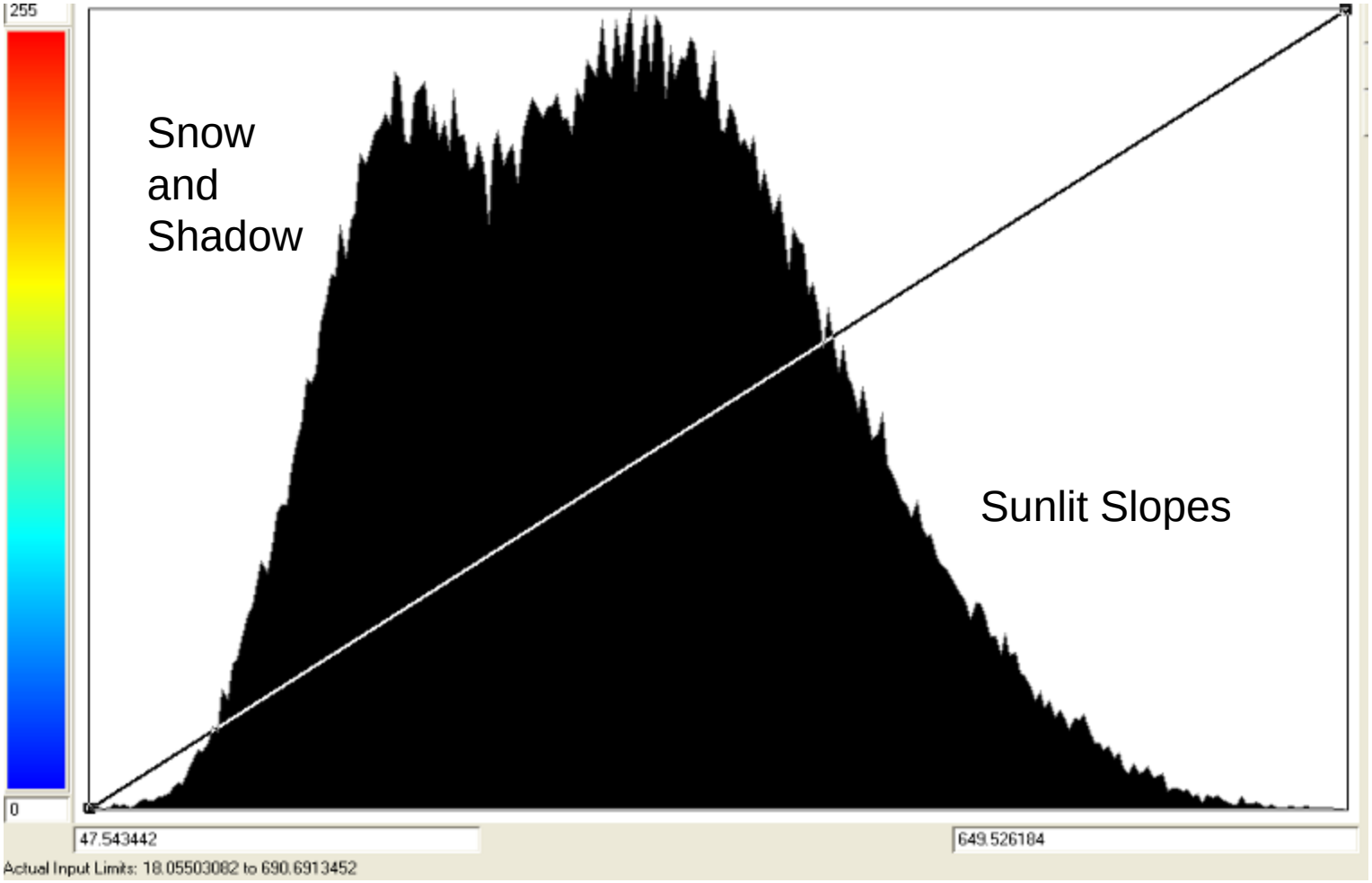
Zoom of Peak Temperature



Surface Temperature

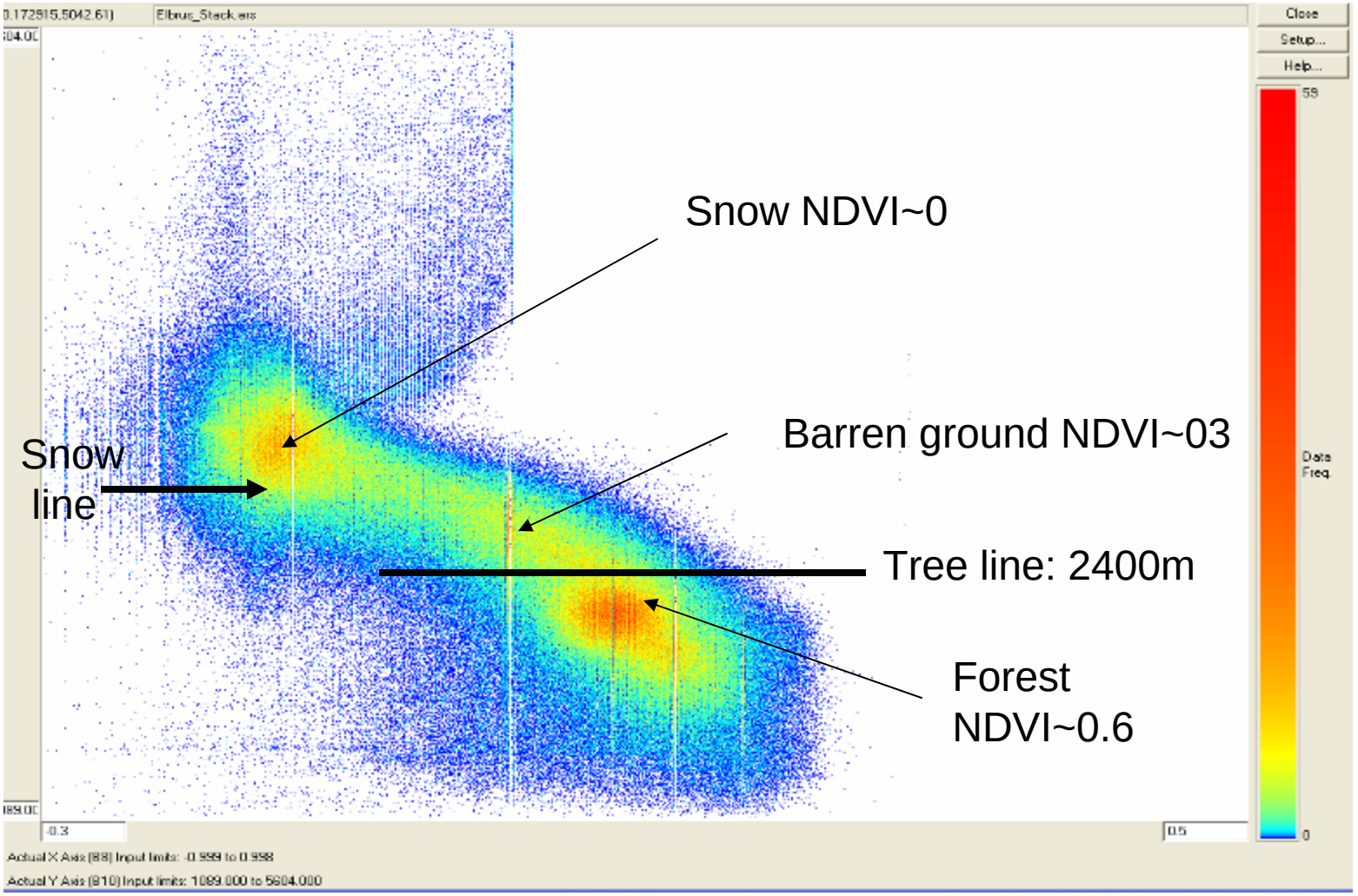


Temperature Histogram



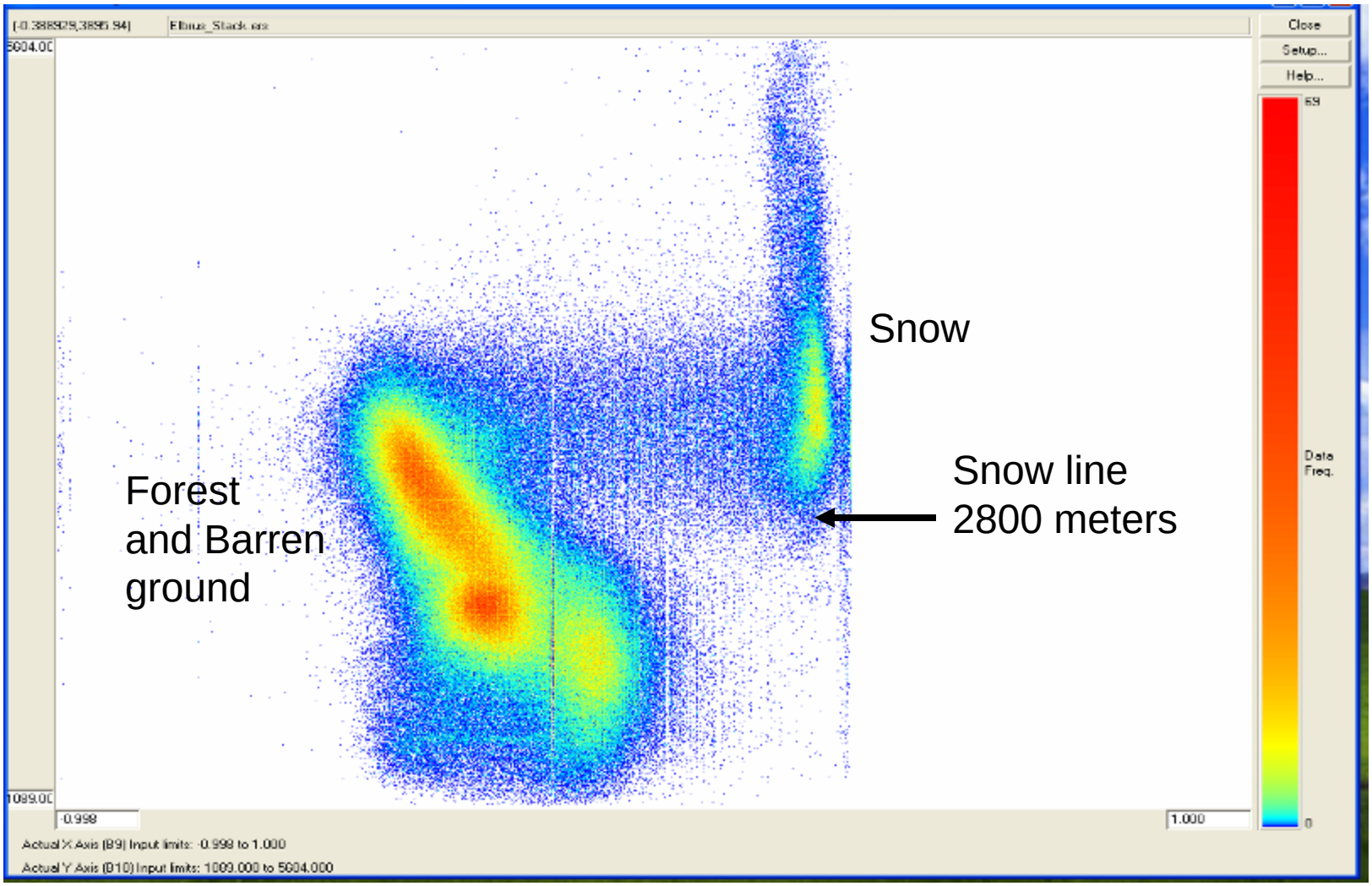
Sensible Heat Flux (W/m2) Histogram

Elevation

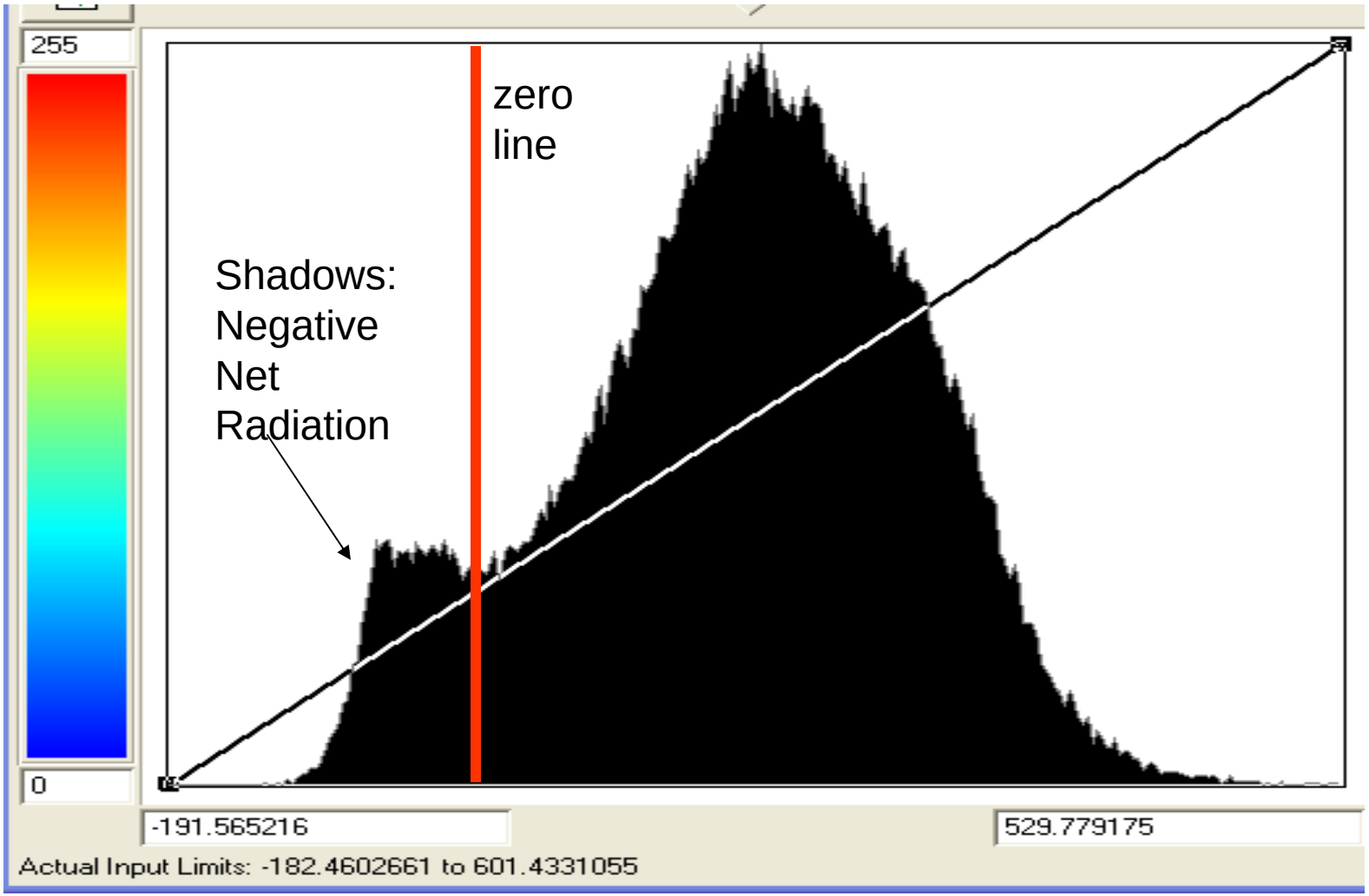


NDVI versus Elevation

Elevation



Snow Index versus elevation



Net Radiation (W/m2)

Latent Heat Flux: Options

1. Assume evaporation is proportional to surface temperature
2. Include an NDVI correction (more vegetation: more ET)
3. Use a Bowen ratio for each land cover type.