First, this presentation will show the basic, general knowledge of satellite imagery of each channels.

Thereafter, this presentation will show RGB image composites.
Objectives

- Learn the basic, general knowledge of satellite imagery of each channels.
- Especially, we learn the characteristics of the sensors onboard MTSAT-1R.
- Learn how to use (interpret) the differences.
- Learn RGB image composites.
- This material shows you the RGB composite examples applied the technique of RGB to MTSAT images.
We will mention the feature of individual JAMI channels, before reference of RGB composite image.

**Resolution**

The characteristics of a sensor on board the MTSAT-1R are shown in Table. The horizontal spatial resolution of the MTSAT-1R is 1 km in the VIS image and 4 km in the IR images at the sub-satellite point (SSP). The more distant from SSP, the more the earth’s surface is viewed obliquely and the resolution deteriorates. In the vicinity of Japan, the resolution is 1.4 km in the VIS image and 5 km in the IR images.

The gray scale of MTSAT-1R images is 10 bits (1024 levels) in the VIS and IR images.
MTSAT-1R/JAMI

<table>
<thead>
<tr>
<th></th>
<th>Nadia spatial res.</th>
<th>Quantization</th>
<th># of obs. par day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VIS</td>
<td>IR</td>
<td>VIS</td>
</tr>
<tr>
<td>MTSAT</td>
<td>1 km</td>
<td>4 km</td>
<td>10 bits</td>
</tr>
<tr>
<td>GMS5</td>
<td>1.25 km</td>
<td>5 km</td>
<td>6 bits</td>
</tr>
</tbody>
</table>

SRFs of infrared channels

MTSAT-1R’s platform is as follows.
Nadia spatial resolution and quantization is modified compared to GMS-5.
Half disk observation started to derive AMVs.
This is SRFs (spectral response functions) of infrared channel.
## MSG Channels

<table>
<thead>
<tr>
<th>Channel No.</th>
<th>Spectral Band (μm)</th>
<th>Characteristics of Spectral Band (μm)</th>
<th>Main Observational Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VIS 0.6</td>
<td>0.635 0.56 0.71</td>
<td>Surface, clouds, wind fields</td>
</tr>
<tr>
<td>2</td>
<td>VIS 0.8</td>
<td>0.81 0.74 0.88</td>
<td>Surface, clouds, wind fields</td>
</tr>
<tr>
<td>3</td>
<td>NIR 1.6</td>
<td>1.64 1.50 1.78</td>
<td>Surface, cloud phase</td>
</tr>
<tr>
<td>4</td>
<td>IR 3.9</td>
<td>3.90 3.48 4.36</td>
<td>Surface, clouds, wind fields</td>
</tr>
<tr>
<td>5</td>
<td>WV 6.2</td>
<td>6.25 5.35 7.15</td>
<td>Water vapor, high level clouds, atmospheric instability</td>
</tr>
<tr>
<td>6</td>
<td>WV 7.3</td>
<td>7.35 6.85 7.85</td>
<td>Water vapor, atmospheric instability</td>
</tr>
<tr>
<td>7</td>
<td>IR 8.7</td>
<td>8.70 8.30 9.10</td>
<td>Surface, clouds, atmospheric instability</td>
</tr>
<tr>
<td>8</td>
<td>IR 9.7</td>
<td>9.66 9.38 9.94</td>
<td>Ozone</td>
</tr>
<tr>
<td>9</td>
<td>IR 10.8</td>
<td>10.80 9.80 11.80</td>
<td>Surface, clouds, wind fields, atmospheric instability</td>
</tr>
<tr>
<td>10</td>
<td>IR 12.0</td>
<td>12.00 11.00 13.00</td>
<td>Surface, clouds, atmospheric instability</td>
</tr>
<tr>
<td>11</td>
<td>IR 13.4</td>
<td>13.40 12.40 14.40</td>
<td>Cirrus cloud height, atmospheric instability</td>
</tr>
<tr>
<td>12</td>
<td>HRV</td>
<td>Broadband (about 0.4 – 1.1 μm)</td>
<td>Surface, clouds</td>
</tr>
</tbody>
</table>

Spectral channel characteristics of SEVIRI in terms of central, minimum and maximum wavelength of the channels and the main application areas of each channel.

This table shows MSG (METEOSAT Second Generation) channels.
This table shows the correspondence of each channel of MSG and MTSAT-1R.
There are many common things on the image interpretation in the corresponding channels.

<table>
<thead>
<tr>
<th>MTSAT Channels</th>
<th>Wave length (µm)</th>
<th>MSG Channels</th>
<th>Wave length (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIS</td>
<td>0.55~0.90</td>
<td>VIS0.6</td>
<td>0.56~0.71</td>
</tr>
<tr>
<td>IR1</td>
<td>10.3~11.3</td>
<td>IR10.8</td>
<td>9.80~11.80</td>
</tr>
<tr>
<td>IR2</td>
<td>11.5~12.5</td>
<td>IR12.0</td>
<td>11.00~13.00</td>
</tr>
<tr>
<td>IR3(WV)</td>
<td>6.5~7.0</td>
<td>WV6.2</td>
<td>5.35~7.15</td>
</tr>
<tr>
<td>IR4(3.8µm)</td>
<td>3.5~4.0</td>
<td>IR3.9</td>
<td>3.48~4.36</td>
</tr>
</tbody>
</table>
Properties of each channel
Visible (VIS) image

(1) Features of VIS image

VIS image represents the intensity of sunlight reflected from clouds and/or the earth’s surface and makes it possible to monitor the conditions of the ocean, land and clouds. Portions of high reflectance are visualized bright and low reflectance dark. In general, the snow surface and clouds look bright because they have high reflectance, the land surface is darker than the clouds, and the sea surface looks the darkest because of its low reflectance. Note, however, that the appearance differs depending on the solar elevation at the observed point. In the morning and evening and in high–latitude districts, the image looks darker because there is little incident light due to the oblique sunlight and the small amount of reflected rays.

(2) Use of VIS image

A. Distinction between thick and thin clouds

The reflectance of a cloud depends on the amount and density of the cloud droplets and raindrops contained in the cloud. In general, low-level clouds contain a larger amount of cloud droplets and raindrops and therefore they appear brighter than high clouds. Cumulonimbus and other thick clouds that have developed vertically contain a lot of cloud droplets and raindrops and they appear bright in a VIS image. Through some thin high-level clouds, the underlying low-level clouds and land or sea surface can be seen.

B. Distinction between convective and stratiform types

Cloud types can be identified from the texture of the cloud top surface. The top surface of a stratiform cloud is smooth and uniform while the top surface of a convective cloud is rugged and uneven. The texture of a cloud top surface is easily observed when sunlight is hitting the cloud top obliquely.

C. Comparison of cloud top height

If clouds of different heights coexist when sunlight is hitting them obliquely, it may happen that the cloud of the higher top height casts a shadow onto the cloud surface of the lower top height. Comparison of cloud height is possible by this shadow.
Infrared (IR) image

(1) Features of IR image
The IR image represents a temperature distribution and can be observed without a difference between day and night. Therefore, it is useful for watching clouds and/or the earth’s surface temperature. In the IR image, portions of low temperature are visualized bright and portions of high temperature dark.

(2) Use of IR image
A. Watching over meteorological phenomena
Unlike the VIS image, observation is possible with the IR image under the same conditions against day or night. This is the most advantageous point in watching meteorological disturbances.

B. Observation of cloud top height
It is possible to know the cloud top temperature with the IR image. If the temperature profile of atmosphere is known, the cloud top temperature can be converted into cloud top height. For the estimation of the temperature profile, values by objective analysis or Numerical Weather
Use of WV image

A. Grasp of airflow in the upper and middle air

The WV image is possible to represent the radiation from the water vapor content in the upper and middle layer. That is, the airflow in the upper and middle layer can be visualized using water vapor as a tracer even if no cloud is present. The position of troughs, vortices and jet streams in the upper and middle layer can be estimated from the distribution of bright and dark areas on the WV image.
Use of 3.8μm image

Main application:
- Identification of lower clouds in the night
- Identification of upper clouds
- Detection of fires
- Microphysical cloud properties (particle size)

03UTC 21 July 2006
MTSAT-1R image

Use of 3.8-μm image

A. Identification of lower clouds in the night

Lower clouds have a small temperature difference with the surrounding cloud free areas and it is difficult to detect them at night in the IR image alone. The cloud top temperature is calculated lower at 3.8-μm than at IR1 and the difference of calculated temperature is 2 to 10 degrees negative. The 3.8-μm differential image is used for the lower cloud identification in the night because the differences between cloud free area and lower cloud area are more intensified in the 3.8-μm differential image than in the 3.8-μm image.

B. Identification of upper clouds

The 3.8-μm rays have properties that are close to visible light and they easily penetrate the higher cloud with ice crystals. At night, the radiations from the earth’s surface at high temperature penetrate thin higher clouds and are added to the radiations from the cloud top, so the cloud top temperature calculated at 3.8-μm is higher than actual. Because the transmission effect is larger at 3.8-μm than at IR1, the cloud top temperature is higher than the infrared temperature and the temperature difference has a positive value. In this regard, the area of thin higher clouds can be identified with the 3.8-μm differential image. For example, it is possible to distinguish between cumulonimbus, which brings about rainfall, and anvil cirrus, which does not.
Differences/ratios of 2 channels
(Extraction from the materials of MSG, EUMETSAT)

- Simply displaying a larger set of single channels for comparison is neither efficient in meaning useful information nor particularly focused on phenomena of interest;
- Displaying specific channel differences or ratios, a simple operation though, improves the situation awareness by enhancing particular phenomenon of interest (e.g. fog or ice clouds) in a particular situation;
- Grey-scale rendering (small values in dark or light shades – large values in light or dark shades) is not standardised; mode may be inherited from similar products based on data of other imagers (e.g. AVHRR or MODIS).

The text on this slide is practically self-explaining.
Some recommended differences

- Clouds
  - IR10.8-IR12.0
  - IR10.8-IR3.9
- Thin cirrus
  - IR10.8-IR12.0
- Fog
  - IR10.8-IR3.9
- Volcanic Ash
  - IR10.8-IR12.0
- Dust
  - IR10.8-IR12.0
- Fire
  - IR3.9-IR10.8

Note difference of day and night on channel4.
Applications of IR1 – IR2

- Identification of thin (high) clouds
- Identification of volcanic ash and dust
- Low-level humidity
- Sea surface temperature
- ...

MTSAT-1R, 21 July 2006 03UTC

Infrared differential image

Features of infrared differential image

The infrared differential image is a visualization of the temperature at IR1 from which the temperature at IR2 is subtracted. These infrared bands are called the atmospheric windows where there is little absorption by water vapor and the atmosphere. However, the absorption by water vapor cannot be always neglected. Absorbency is larger in the IR1 band than in the IR2 band though the difference is slight. The difference in absorbency between IR1 and IR2 depends on the water vapor content of the atmosphere, and the infrared differential image is visualized darker for larger values of this difference.
In certain case, it is often difficult to analyze the imagery without animation.
## Summary of MTSAT Representation

<table>
<thead>
<tr>
<th>VIS</th>
<th>low albedo</th>
<th>high</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR (IR1,IR2)</td>
<td>low temp.</td>
<td>high</td>
</tr>
<tr>
<td>WV (IR3)</td>
<td>wet humidity</td>
<td>dry</td>
</tr>
<tr>
<td>3.8 μm (IR4, day)</td>
<td>low albedo</td>
<td>high</td>
</tr>
<tr>
<td>3.8 μm (IR4, night)</td>
<td>low temp.</td>
<td>high</td>
</tr>
<tr>
<td>IR1–IR2</td>
<td>dust, ash</td>
<td>thin Ci</td>
</tr>
<tr>
<td>IR4–IR1 (day)</td>
<td>large ice</td>
<td>small ice</td>
</tr>
<tr>
<td>IR4–IR1 (night)</td>
<td>fog</td>
<td>thin Ci</td>
</tr>
</tbody>
</table>

### Comparison of images

In the VIS image, the gray scale is represented white for high reflectance and black for low reflectance. In the IR image, it is represented black for high temperature and white for low temperature as same as the gray scales ordinary used. In the infrared differential image, it is represented black for large (positive) differences and white for small (negative) differences. In the 3.8-μm image, the gray scale in the day is represented black for high reflectance and white for low reflectance. Note that this is opposite to the VIS image. At night, the same gray scale as the IR image is used. The 3.8-μm differential image is represented black for positive differences and white for negative differences (Table).

### Table. Appearance in images

<table>
<thead>
<tr>
<th>Image types</th>
<th>Appearance in images</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>Light gray</td>
</tr>
<tr>
<td></td>
<td>Gray</td>
</tr>
<tr>
<td></td>
<td>Dark gray</td>
</tr>
<tr>
<td></td>
<td>Black</td>
</tr>
<tr>
<td>Visible image</td>
<td>Reflection large</td>
</tr>
<tr>
<td></td>
<td>Reflection small</td>
</tr>
<tr>
<td>Infrared image</td>
<td>Temperature low</td>
</tr>
<tr>
<td></td>
<td>Temperature high</td>
</tr>
<tr>
<td>Water vapor image</td>
<td>Wet</td>
</tr>
<tr>
<td></td>
<td>Dry</td>
</tr>
<tr>
<td>3.8-μm image (day)</td>
<td>Reflection small</td>
</tr>
<tr>
<td></td>
<td>Reflection large</td>
</tr>
<tr>
<td>3.8-μm image (night)</td>
<td>Temperature low</td>
</tr>
<tr>
<td></td>
<td>Temperature high</td>
</tr>
<tr>
<td>Infrared differential image</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>3.8-μm differential image</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>Positive</td>
</tr>
</tbody>
</table>
(Cloud) Physical Properties represented by the MTSAT Channels

VIS(0.55-0.90): optical thickness and amount of cloud water and ice
IR4 (IR3.8): particle size and phase
WV (IR3): mid- and upper level moisture
IR1 (IR11.0), IR2 (IR12.0): top temperature

IR2 - IR1: optical thickness
IR4 - IR1: optical thickness, phase, particle size
WV - IR1: top height, overshooting tops
We often analyze images by using each individual channel alone, and it is important to determine the kind of the cloud by animation. However, considerable skill is necessary for that.

RGB image composites can be determined easily by appearance, it is very effective for the neph-analysis.
RGB: red, green, and blue

RGB means the three primary colors of the light, and it is composed of the color space representing an additive color system.

The scheme on this slide shows the system;
Primary colors: red, green, and blue
Secondary colors: yellow = red + green

\[
\begin{align*}
\text{cyan} &= \text{green} + \text{blue} \\
\text{magenta} &= \text{red} + \text{blue}
\end{align*}
\]

All colors: white = red + green + blue

\[
\text{black} = \text{no light}
\]

RGB image composite is a technique to display the color imagery by using this property of the three primary colors of the light.
RGB image composites - additive colour scheme
(Extraction from the materials of MSG, EUMETSAT)

Attribution of images of 2 or 3 channels (or channel differences/ratios) to the individual colour (RGB) beams of the display device;

- RGB display devices produce colours by adding the intensities of their colour beams → optical feature extraction through result of colour addition.

⇒ FAST BUT QUITE EFFICIENT SURROGATE FOR QUANTITATIVE FEATURE EXTRACTION

The text on this slide is practically self-explaining.
RGB image composites
- how to do

Optimum (and stable) colouring of RGB image composites depends on some manipulations:

- Proper enhancement of individual colour channels requires:
  - Some stretching of the intensity ranges;
  - Reflectivity enhancement at lower solar angles applying e.g. sun angle compensation or histogramme equalisation;
  - Selection of either inverting or not IR channels.

- Attribution of images to individual colour beams depends on:
  - Reproduction of RGB schemes inherited from other imagers;
  - Permutation among colour beams of individual images → more or less pleasant / high-contrast appearance of RGB image composite.

Extraction from the materials of MSG, EUMETSAT

(Extraction from the materials of MSG)
RGB image composites
- pros and cons

■ Drawbacks:
  ■ Much more subtle colour scheme compared to discrete LUT used in quantitative image products → interpretation more difficult;
  ■ RGBs using solar channels loose colour near dawn/dusk (even with reflectivity enhancement).

■ Advantages:
  ■ Processes “on the fly”;
  ■ Preserves “natural look” of images by retaining original textures (in particular for clouds);
  ■ Preserves spatial and temporal continuity allowing for smooth animation of RGB image sequences.

(Extraction from the materials of MSG)
RGB in MTSAT Image

When we use the channels of MTSAT, we can use the combinations of EUMETSAT, such as "Day Microphysical", "Night Microphysical" and "Severe Convection" as combinations of RGB.

- **~General cloud analysis, cloud microphysics~**
  - "Day Microphysical"
    - VIS(0.55-0.90), IR4(3.8), IR1(11.0)
  - "Night Microphysical"
    - IR2(12.0)-IR1(11.0), IR1(11.0)-IR4(3.8), IR1(11.0)

- **~Severe convective storms, typhoons~**
  - "Severe Convection"
    - VIS(0.55-0.90), IR4(3.8)-IR1(11.0), IR1(11.0)
MTSAT-1R have only 5 channels, so we can't have various combination of RGB composite image, but we will enumerate some examples that seem to be effective to watch imagery.

This case is tentative (trial) RGB image composite. This composite corresponds to “Day Microphysical” (RGB 02,04r,09). Notice that the image of IR4 (3.8 $\mu$m) contains total (solar, thermal) contributions. The true composites “Day Microphysical” contain only solar contribution for 3.9 $\mu$m channel. Moreover, while gamma value of IR4 is 1 in this case, the value for “Day Microphysical” is 2.5.

However, we can derive useful information from this image. In addition to lower cloud and upper cloud, we can distinguish fog (or Sc)!
This case is also tentative (trial) RGB image composite.

This composite pattern correspond to Day Microphysical (RGB 02,04r,09) in MSG.

Notice that the image of IR4 (3.8 μ m) contains total (solar, thermal) contributions.

However, we can get the image similar to MSG image.

This image is obtained by adjusting brightness and the contrast of the images of each channel.

In this image, thick clouds (large ice) of typhoon appear in reddish color, thick ice clouds (small ice) appear in orangish color, low-level water clouds appear in white-greenish color.

Thus we can analyze the structure of typhoon easily.
RGB image composites for Night Microphysical

- IR3.8—IR11.0 differential image
- IR11.0—IR12.0 differential image
- IR11.0 (Inversion) image

RGB image composites for Night Microphysical
RGB image composites by MTSAT-1R images (Night Microphysical)

R: IR 11.0 - IR 12.0
- low-level clouds
- mid-level clouds
- thick high-level clouds

G: IR 3.8 - IR 11.0
- low-level clouds
- mid-level clouds

B: IR 11.0 (Inversion)
- low-level clouds
- mid-level clouds
- thin high-level clouds

(MTSAT-1R, 25 June 2007, 12UTC)

- convective clouds / thick clouds
- low-level clouds / fog
- high-level clouds
- low-level thick clouds
- mid-level clouds
This composite pattern correspond to Night Microphysical (RGB 10-09,09-04,09) in MSG.

Notice that the image of IR4 (3.8μm) is not CO2-corrected brightness temperature.

However, we can get the image similar to MSG image.

This image is obtained by adjusting brightness and the contrast of the images of each channel.

In this image, thick Cb of typhoon at night appear in sprinkled orange-red color. The source of noise are IR4 (3.8μm).
This composite pattern correspond to Night Microphysical (RGB 10-09,09-04,09) in MSG.

Notice that the image of IR4 (3.8 \( \mu \)m) is not CO2-corrected brightness temperature.

However, we can get the imagery similar to MSG's composite imagery. This image is obtained by adjusting brightness and the contrast of the images of each channel.

In this image, thick Cb of typhoon at night appear in sprenkled orange-red color, and thin cirrus appear in dark bluish color.

The source of noise are IR4 (3.8\( \mu \)m).
This composite pattern correspond to Night Microphysical (RGB 10-09,09-04,09) in MSG, too.

Notice that the image of IR4 (3.8 μm) is not CO2-corrected brightness temperature.

However, we can get the imagery similar to MSG imagery.

This image is obtained by adjusting brightness and the contrast of the images of each channel.

In this image, the convective clouds appear in sprinkled orange-red color, thin cirrus appears in dark bluish color.
This composite pattern correspond to Night Microphysical (RGB 10-09-09,09) in MSG, too.

This image is obtained by adjusting brightness and the contrast of the images of each channel.

In this image, night-time fog (or low cloud) appears in pinkish white.

We have to adjust this more, but we could make a clear distinction.
This composite pattern correspond to Night Microphysical (RGB 10-09,09-04,09) in MSG, too.

These images are the same as the image of the previous slide and are obtained by adjusting brightness and the contrast of the images of each channel.

In these images, night-time fog (or low cloud) appears in pinkish white.

Notice that SATAID does not have the function for gamma correction, therefore we have to use the retouch software in common use.
Severe Convection in SATAID Image

Mixture image
VIS: Red
IR4-IR1: Green
IR1: Blue

Convective Cloud: Pacific Ocean

Very cold, Convective Clouds

(MTSAT-1R, 24 August 2006, 23UTC)

This case is also tentative (trial) RGB image composite. This composite pattern correspond to Severe Convection (RGB 02,04-09,09) in MSG. This image is obtained by adjusting brightness and the contrast of the images of each channel. In this image, convective cloud appears in yellowish - orangish color.
This example is RGB composite imagery of fire detection in north western China and Siberia. The forest fires are highlighted by 3.8 μm (IR4) and its brightness temperature difference (IR1-IR4) imagery.
Summary of RGB image composites

- Fast technique for feature enhancement exploiting additive colour scheme of RGB displays;
- May require simple manipulation to obtain optimum colouring (choice of inverting for IR channels!);
- More complex RGB schemes may require some time to get acquainted with;
- Some RGB schemes may be inherited from other imagers (e.g. AVHRR or MODIS);
- Combination of an IR channel with HRV feasible and much informative;
- RGB image composites retain natural texture of single channel images;
- RGB image composites remain coherent in time and space, i.e. ideal for animation of image sequences.
Summary of RGB image composites for MTSAT-1R

- MTSAT-1R has only 5 channels, so we can't have various combination of RGB composite image.

- There is a possibility that this method can be applied to the imagery of MTSAT-1R, though there are some limitations.

- It is necessary to use 3.8µm channel that we have to consider solar and thermal contributions.

- Other channel selection, gamma correction, stretching of intensity ranges, etc...

The text on this slide is practically self-explaining.
THE END

SATAID: mscweb.kishou.go.jp/VRL/

JMA: www.jma.go.jp/jma/indexe.html

The author is most appreciative of the kind cooperation of Training Division (EUMETSAT).
IR3.9: SOLAR AND THERMAL CONTRIBUTION
(Extraction from the materials of MSG, EUMETSAT)
SEVIRI CHANNELS:

IR3.9 μm

Signal in IR3.9 channel comes from reflected solar and emitted thermal radiation!

Consequence for Planck relation between radiance and temperature: during day-time, temperature is not representative of any in situ temperature (see next slide)!
Schematic: Blackbody Radiation for T=300K (actual scene temperature)

IR3.9 Radiance Measurement: 300K + reflected sunlight

IR3.9 Radiance at 300K

Schematic: Blackbody Radiation for T=350K (satellite measured scene temperature)

Radiance Intensity

Wavelength

3.9

Annex
IR3.9: CLOUD PHASE AND PARTICLE SIZE (MAINLY DAY-TIME)
Reflection of Solar Radiation at IR3.9

- Reflection at IR3.9 is sensitive to cloud phase and very sensitive to particle size
- Higher reflection from water droplets than from ice particles
- During daytime, clouds with small water droplets (St, Sc) are much darker than ice clouds
- Marine Sc (large water droplets) is brighter than Sc over land
Due to the high reflection from water droplets at IR3.9, low-level water clouds are much darker than high-level ice clouds (during day-time).
IR3.9 shows much more cloud top structures than IR10.8 (very sensitive to particle size)

1 = ice clouds with very small particles
2 = ice clouds with small particles
3 = ice clouds with large ice particles

Channel 04 (IR3.9)  Channel 09 (IR10.8)

MSG-1, 20 May 2003, 13:30 UTC
NOISE IN THE IR3.9 CHANNEL
Noise in the IR3.9 Channel

- At IR10.8, equivalent brightness temperatures can be determined very accurately at both warm and cold scene temperatures.
- At IR3.9, the radiance increases rapidly with increasing temperature (see next slide).
- Since measurement accuracy is constant, the result is a much less accurate temperature measurement at cold scene temperatures in the IR3.9 channel.
At IR3.9, a small change in radiance corresponds to a large change in temperature.
During the night, the IR3.9 channel cannot be used for cold cloud tops. Below BTs of 220 K the IR3.9 channel is very noisy (radiances close to zero).

<table>
<thead>
<tr>
<th>RAW</th>
<th>RAD</th>
<th>TEMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>[count]</td>
<td>[mW/m²]</td>
<td>[K]</td>
</tr>
<tr>
<td>54</td>
<td>0.01</td>
<td>218</td>
</tr>
<tr>
<td>53</td>
<td>0.01</td>
<td>213</td>
</tr>
<tr>
<td>52</td>
<td>0.00</td>
<td>205</td>
</tr>
<tr>
<td>51</td>
<td>0.00</td>
<td>131</td>
</tr>
</tbody>
</table>

Interpretation: IR3.9 imagery does a fine job for warm scene temperatures, but at night it is not useful for cold scenes like thunderstorm tops.