Compilation of RGB Recipes

How to create the standard RGB images from METEOSAT/SEVIRI and MetOp/AVHRR and VIIRS data?

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Introduction

This document contains descriptions (the so-called 'recipes') on how to create the EUMETSAT suggested standards RGB types from METEOSAT/SEVIRI and MetOp/AVHRR data, as well as from VIIRS data. For each RGB type a table contains the needed parameters.

Colour beam	Channel (difference)	Range			Gamma
Red		MIN1	MAX1	K or %	Gamma1
Green		MIN2	MAX2	K or %	Gamma2
Blue		MIN3	MAX3	K or %	Gamma3

Table 1: Template of the parameters used in the RGB recipes

The second column shows which channels (or channel differences) should be visualised in the red, green and blue colours beams. Before combining them, these images should be calibrated and enhanced.

- The measured values should be *calibrated* by calculating reflectivity (R) or brightness temperature (BT) values. In case of solar channels, the calibration should include solar zenith angle correction as well: the reflectivity should be divided by the cosine of the solar zenith angle. (The zenith angle should be capped e.g. at 80 degree.)
- Then the images should be *enhanced*. The enhancement expands the range (MIN, MAX) of R or BT values to the full range of display values (0-255, BYTE) by a linear stretching and possibly a non-linear stretching.
  - The images should be *linearly stretched* within the brightness temperature or reflectivity ranges. (The 3rd and 4th columns of Table 1 contain the lower and upper limit of the corresponding ranges, while the 5th column contains the unit. In some cases, the range is 'inverted': the MAX and the MIN values are reversed.)
  - In some cases, a *non-linear stretching* is also needed. In case of VIIRS True Colour RGB this is a piecewise linear expansion. In the other cases a so-called gamma correction is performed. If gamma parameter is greater than 1 then the image becomes brighter and the contrast of the darker tones increases. If gamma parameter is lower than 1 then the image becomes darker and the contrast of the brighter tones increases. If gamma is equal to 1 then no gamma correction is needed. (The 6th column contains the Gamma parameter.)

The equation of the gamma correction:

$$\boldsymbol{BYTE = 255 * \left(\frac{X - MIN}{MAX - MIN}\right)^{\frac{1}{Gamma}}}$$

where

- X is the input value - the actual calibrated value: reflectivity (R) or brightness temperature (BT),
- MIN and MAX are the lower and upper limit of the range of the stretching,
- Gamma is the parameter of the gamma correction,
- BYTE is the output value – the intensity of the enhanced image (if the full range of display value is 0-255).

In case of ***VIIRS data*** a 'bow-tie correction' is also needed. To do this one can use several program packages, for example 'Polar2grid' (https://www.ssec.wisc.edu/software/polar2grid/) or Pytroll (https://pytroll.readthedocs.io/en/latest/quickstart_viirs.html). They process the channels separately, performing bow-tie correction* and calibration. The results are reflectivity for shortwave channels and brightness temperatures for longwave channels together with the geographical coordinates and the satellite and solar viewing angles. Using the georeferenced and calibrated channel data one can create the RGB images and visualised them on maps.

*VIIRS uses a unique approach of pixel aggregation which controls the pixel growth towards the end of the scans. As a result, the VIIRS spatial resolutions for nadir and edge-of-scan data are more comparable. However, because of this processing the raw image contains stripes towards the edge of the image and duplicated pixels. The bow-tie correction eliminates the stripes and the duplicated pixels.

METEOSAT/SEVIRI RGB recipes

Airmass RGB

Airmass RGB was originally tuned for mid-latitude regions. However, it turned out that it is not optimal for the tropical region. With the original tuning the colour of the tops of the tropical convective clouds became saturated (all white – no cloud structure). The main reason is that the tops of convective clouds in the tropics are much colder than at mid-latitudes.

The recipes of the two versions are described in the next two pages.

Airmass RGB - tuned for the mid-latitudes

Colour beam	Channel (difference)	Range			Gamma
Red	WV6.2 – WV7.3	-25	0	K	1
Green	IR9.7 – IR10.8	-40	+5	K	1
Blue	WV6.2 inverted	243	208	K	1

The table shows which channels or channel differences are visualised in the red, green and blue colour beams. The measured values should be first calibrated to brightness temperatures. The channels or channel differences should be then enhanced – linearly stretched - within the brightness temperature ranges shown in the table. No gamma correction is applied.

Airmass RGB – tuned for the tropics

Colour beam	Channel (difference)	Range			Gamma
Red	WV6.2 – IR10.8	-25	+5	K	1
Green	IR9.7 – IR10.8	-30	+25	K	1
Blue	WV6.2 inverted	243	190	K	1

The table shows which channels or channel differences are visualised in the red, green and blue colour beams. The measured values should be first calibrated to brightness temperatures. The channels or channel differences should be then enhanced – linearly stretched - within the brightness temperature ranges shown in the table. No gamma correction is applied.

Dust RGB

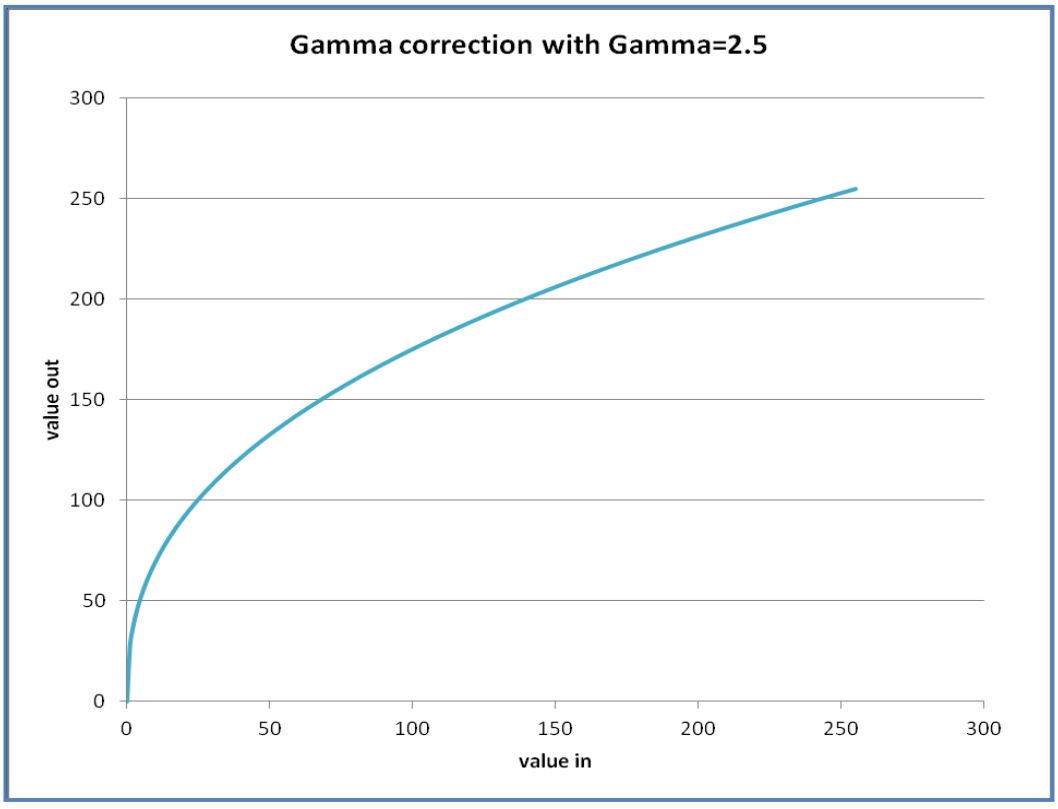
Colour beam	Channel (difference)	Range			Gamma
Red	IR12.0 – IR10.8	-4	+2	K	1.0
Green	IR10.8 – IR8.7	0	+15	K	2.5
Blue	IR10.8	261	289	K	1.0

The Dust RGB is composed of the IR8.7, IR10.8 and the IR12.0 channel data. The input values are calibrated brightness temperatures [K].

Before creating the RGB, the images should be enhanced in two steps.

- First a linear stretch is performed within the indicated ranges.
- Then a gamma correction is applied for the green component.

The gamma correction performs a non-linear expansion. It enhances the contrast either in the darker or in the brighter tones (depending on the Gamma parameter) and it makes the image darker or brighter. In case of the green component of Dust RGB (where Gamma is equal to 2.5), the contrasts of the darker tones are increased, see the figure below.



Effect of the gamma correction if the Gamma parameter is equal to 2.5

24-hour Microphysics RGB

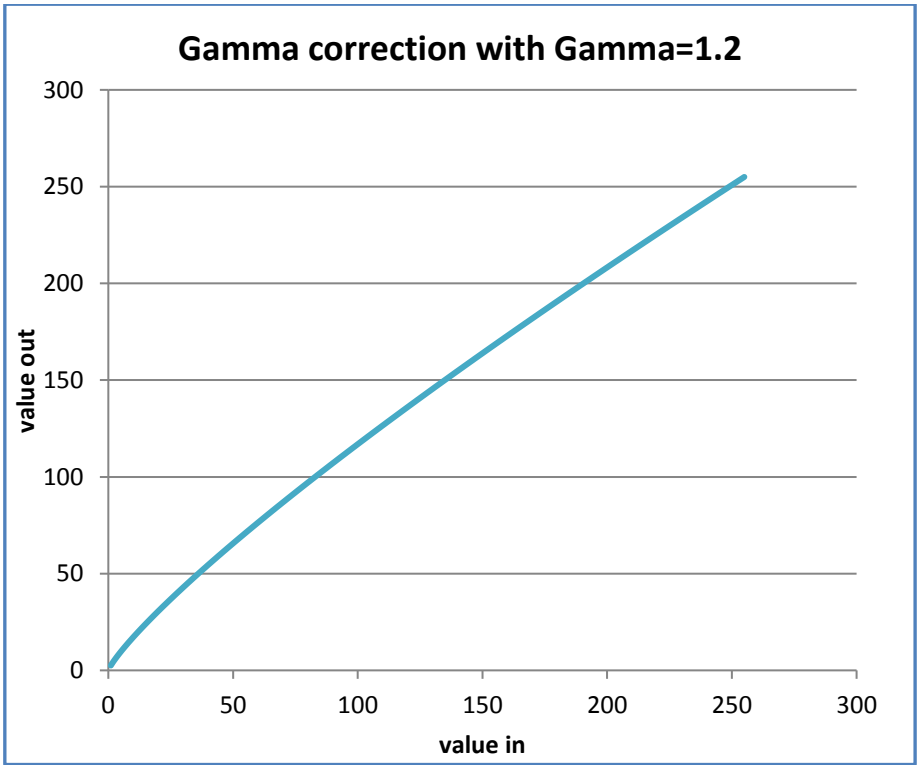
Colour beam	Channel (difference)	Range			Gamma
Red	IR12.0 – IR10.8	-4	+2	K	1.0
Green	IR10.8 – IR8.7	0	+6	K	1.2
Blue	IR10.8	248	303	K	1.0

The 24-hour Microphysics RGB is composed of the IR8.7, IR10.8 and the IR12.0 channel data. The input values are calibrated brightness temperatures [K].

Before creating the RGB, the images should be enhanced in two steps.

- First a linear stretch is performed within the indicated ranges.
- Then a gamma correction is applied for the green component.

The gamma correction performs non-linear expansion. It enhances the contrast either in the darker or in the brighter tones (depending on the Gamma parameter) and it makes the image darker or brighter. In case of the green component of 24-hour Microphysics RGB (where Gamma is equal to 1.2), the contrast of the darker tones are slightly increased, see the figure below.



Effect of the gamma correction if the Gamma parameter is equal to 1.2

Ash RGB

Colour beam	Channel (difference)	Range			Gamma
Red	IR12.0 - IR10.8	-4	+2	K	1
Green	IR10.8 – IR8.7	-4	+5	K	1
Blue	IR10.8	243	303	K	1

The table shows which channels or channel differences are visualised in the red, green and blue colour beams. The measured values should be first calibrated to brightness temperatures. The channels or channel differences should be then enhanced – linearly stretched - within the brightness temperature ranges shown in the table.

Day Microphysics RGB

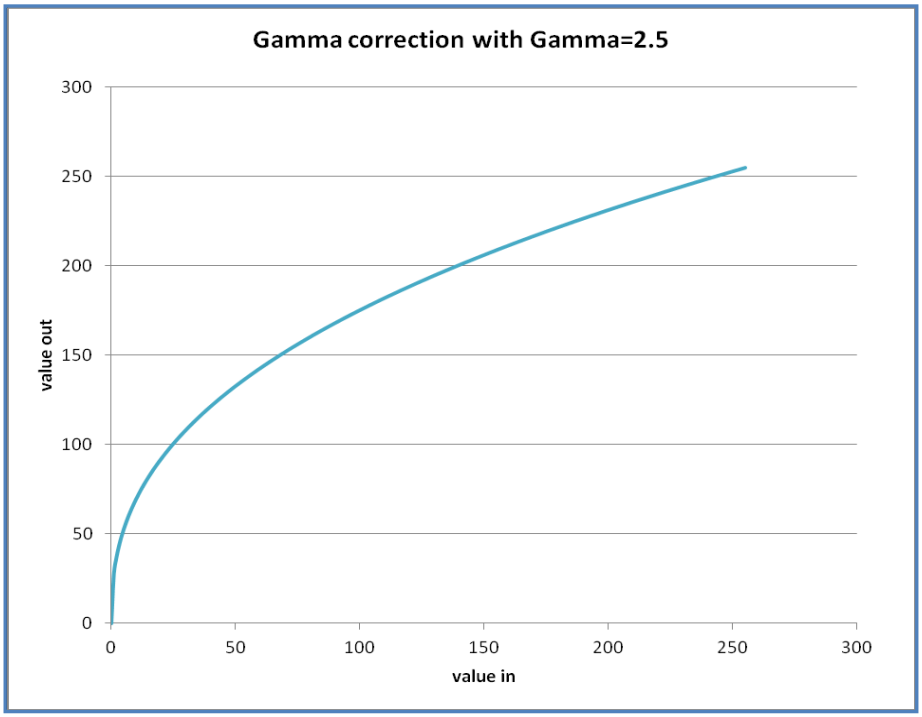
Colour beam	Channel	Range			Gamma
Red	VIS0.8	0	100	%	1.0
Green	IR3.9refl	0	60	%	2.5
Blue	IR10.8	203	323	K	1.0

The Day Microphysics RGB is composed of the VIS0.8, IR3.9 and the IR10.8 channel data. The measured values should be calibrated to calculate reflectivity (including also solar zenith angle correction) from the solar channels and brightness temperature from the thermal channel. During daytime the IR3.9 radiance includes reflected (shortwave) solar contribution as well as emitted thermal radiation. In the Day Microphysics RGB we are only interested in the solar component. To create the Day Microphysics RGB one has to calculate the solar component of the measured IR3.9 signal. The abbreviation IR3.9refl indicates the reflectivity computed from the solar component of the measured IR3.9 radiation.

Before creating the RGB, the images should be enhanced in two steps.

- First a linear stretch is performed within the indicated ranges.
- Then a gamma correction is applied for the green channel.

In case of the green component of Day Microphysics RGB (where Gamma is equal to 2.5), the contrasts of the darker tones are increased, see the figure below.



Effect of the gamma correction if the Gamma parameter is equal to 2.5

Severe Storms RGB

Severe Storms RGB was originally tuned for mid-latitude regions. However, it turned out that it is not optimal for tropical regions. With the original tuning too many convective cloud tops became yellow. The main reason is that the tops of convective clouds in the tropics are much colder than at mid-latitudes.

The recipes of the two versions are described in the next two pages.

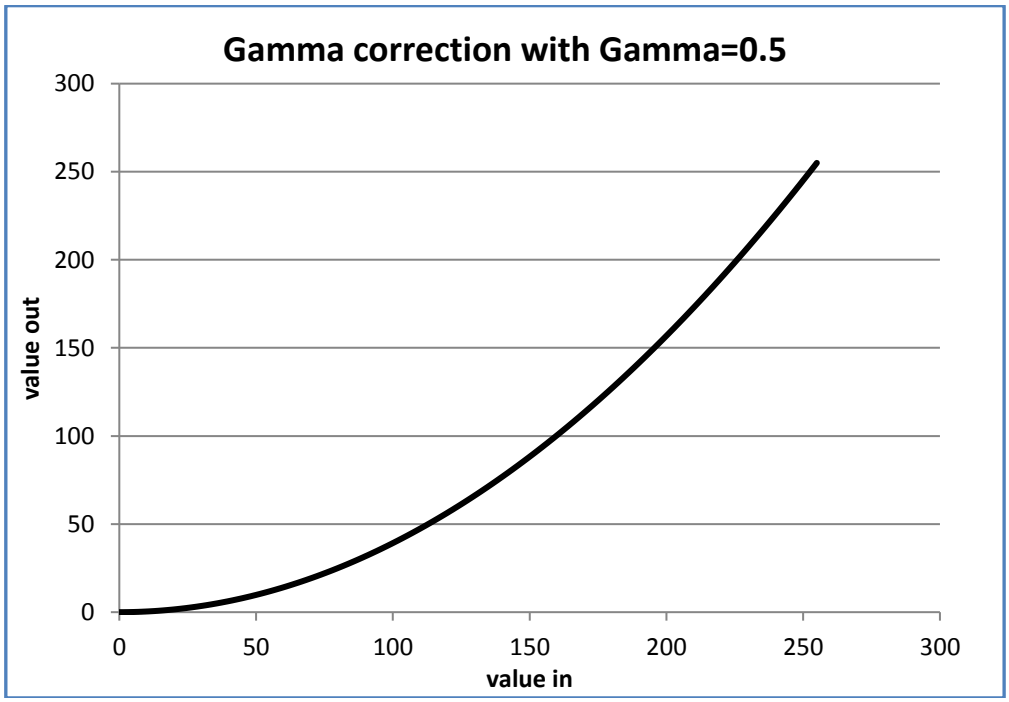
Severe Storms RGB – tuned for the mid-latitudes

Colour beam	Channel difference	Range			Gamma
Red	WV6.2 – WV7.3	-35	+5	K	1
Green	IR3.9 – IR10.8	-5	+60	K	0.5
Blue	NIR1.6 – VIS0.6	-75	+25	%	1

The Table shows which channel differences are visualised in the red, green and blue colour beams. Before combining them, these images should be calibrated and enhanced in one or two steps.

- First a linear stretch is performed within the brightness temperature or reflectivity ranges.
- Then a so-called gamma correction is performed for the green component.

The gamma correction enhances the contrast in the darker or in the brighter tones (depending on the Gamma parameter) and it makes the image darker or brighter. In case of the green component of the Severe Storms RGB (Gamma is equal to 0.5), the contrast of the brighter tones are increased, see the figure below.



Effect of the gamma correction if the Gamma parameter is equal to 0.5

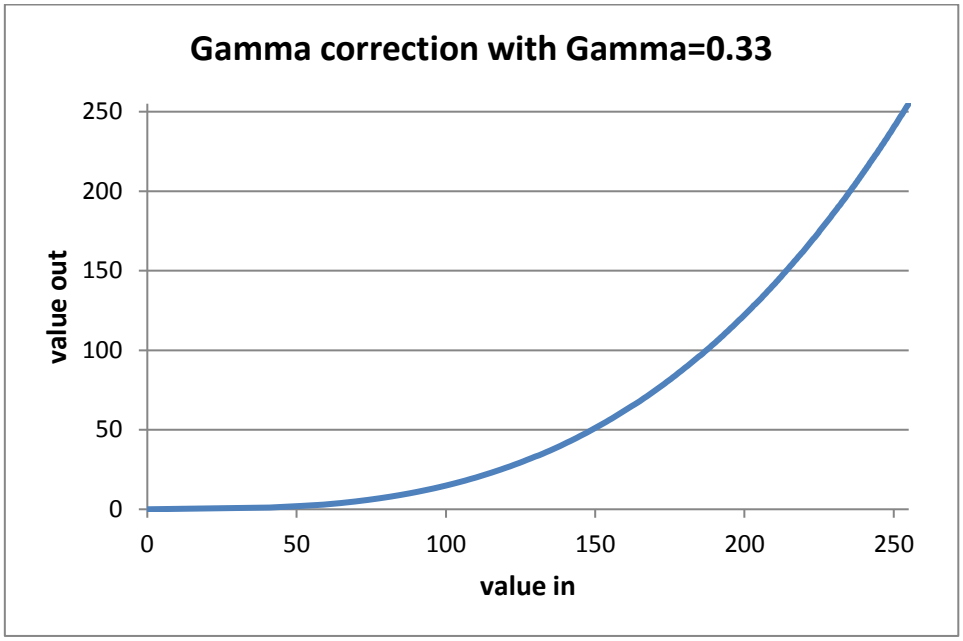
Severe Storms RGB – tuned for the tropics

Colour beam	Channel difference	Range			Gamma
Red	WV6.2 – WV7.3	-35	+5	K	1
Green	IR3.9 – IR10.8	-5	+75	K	0.33
Blue	NIR1.6 – VIS0.6	-75	+25	%	1

The Table shows which channel differences are visualised in the red, green and blue colour beams. Before combining them, these images should be calibrated and enhanced in one or two steps.

- First a linear stretch is performed within the brightness temperature or reflectivity ranges.
- Then a so-called gamma correction is performed for the green component.

The gamma correction enhances the contrast in the darker or in the brighter tones (depending on the Gamma parameter) and it makes the image darker or brighter. In case of the green component of the tropical version of Severe Storms RGB (Gamma is equal to 0.33), the contrast of the brighter tones are increased, see the figure below.



Effect of the gamma correction if the Gamma parameter is equal to 0.33

Snow RGB

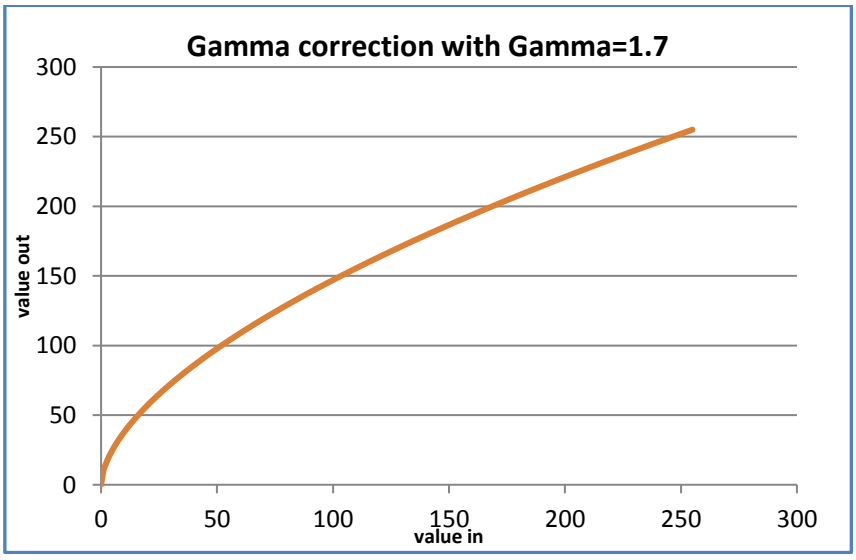
Colour beam	Channel	Range			Gamma
Red	VIS0.8	0	100	%	1.7
Green	NIR1.6	0	70	%	1.7
Blue	IR3.9refl	0	30	%	1.7

The Snow RGB is composed of the VIS0.8, NIR1.6 and the IR3.9 channel data. The measured values should be calibrated to calculate reflectivity (including also solar zenith angle correction). During daytime the IR3.9 radiance includes reflected solar contribution as well as emitted thermal radiation. In the Snow RGB we are interested only in the solar component. To create the snow RGB one has to calculate the solar component of the measured IR3.9 signal. The abbreviation IR3.9refl indicates the reflectivity computed from the solar component of the measured IR3.9 radiation.

Before creating the RGB, the images should be enhanced in two steps.

- First a linear stretch is performed within the indicated reflectivity ranges.
- Then the gamma correction is performed.

The gamma correction performs non-linear expansion. It enhances the contrast either in the darker or in the brighter tones (depending on the Gamma parameter) and it makes the image darker or brighter. In case of the Snow RGB (where Gamma is equal to 1.7), the contrast of the darker tones is increased, see the figure below.



Effect of the gamma correction if the Gamma parameter is equal to 1.7

Natural Colours RGB

Colour beam	Channel	Range			Gamma
Red	NIR1.6	0	100	%	1
Green	VIS0.8	0	100	%	1
Blue	VIS0.6	0	100	%	1

The Natural Colours RGB is composed of the VIS0.6, VIS0.8 and the NIR1.6 channel data. The measured values should be calibrated to calculate reflectivity (including also solar zenith angle correction). The images should then be then enhanced – linearly stretched - within the reflectivity ranges shown in the table.

HRV Clouds RGB

Colour beam	Channel	Range			Gamma
Red	HRV	0	100	%	1
Green	HRV	0	100	%	1
Blue	IR10.8 inverted	323	203	K	1

The HRV Cloud RGB is composed of the High Resolution Visible (HRV) and the IR10.8 channel data.

HRV and IR10.8 channel data have different spatial resolution. It is recommended to use the full resolution of HRV and downscale the IR10.8 image to this higher resolution. The HRV channel is used in two colour beams not to lose the high-resolution appearance.

The measured values should be calibrated to calculate reflectivity (including also solar zenith angle correction) from the solar channel and brightness temperature from the thermal channel. The channels should then be enhanced – linearly stretched - within the brightness temperature and reflectivity ranges shown in the table. No gamma correction is applied.

HRV Fog RGB

Colour beam	Channel	Range			Gamma
Red	NIR1.6	0	70	%	1
Green	HRV	0	100	%	1
Blue	HRV	0	100	%	1

The Table shows which channels are visualised in the red, green and blue colour beams.

HRV and IR10.8 channel data have different spatial resolution. It is recommended to use the full resolution of HRV and downscale the IR10.8 image to this higher resolution. The HRV channel is used in two colour beams not to lose the high-resolution appearance.

The measured values should be calibrated to calculate reflectivity (including also solar zenith angle correction). The images should be then enhanced – linearly stretched - within the reflectivity ranges shown in the table.

Night Microphysics RGB

Night Microphysics RGB was originally tuned for mid-latitude regions. However, it turned out that it is not optimal for tropical regions. The main reason is that the tops low water clouds in the tropics are warmer than at mid-latitudes.

The recipes of the two versions are described in the next two pages.

For high-latitudes the mid-latitude version can be used. However, in cold winter situations, the 24-hour Microphysics RGB is more useful.

Night Microphysics RGB – tuned for the mid-latitudes

Colour beam	Channel (difference)	Range			Gamma
Red	IR12.0 – IR10.8	-4	+2	K	1
Green	IR10.8 – IR3.9	0	+10	K	1
Blue	IR10.8	243	293	K	1

The Night Microphysics RGB is composed of the IR3.9, IR10.8 and the IR12.0 channel data. The input values are calibrated brightness temperatures [K].

The channels should then be enhanced – linearly stretched - within the brightness temperature ranges shown in the table. No gamma correction is applied.

Night Microphysics RGB – tuned for the tropics

Colour beam	Channel (difference)	Range			Gamma
Red	IR12.0 – IR10.8	-4	+2	K	1
Green	IR10.8 – IR3.9	0	+5	K	1
Blue	IR10.8	273	300	K	1

The tropical version of Night Microphysics RGB is composed of the IR3.9, IR10.8 and the IR12.0 channel data. The input values are calibrated brightness temperatures [K].

The channels should then be enhanced – linearly stretched - within the brightness temperature ranges shown in the table. No gamma correction is applied.

MetOp/AVHRR RGB recipes

The AVHRR instrument onboard of the MetOp satellite has fewer channels than the METEOSAT/SEVIRI instrument. It measures in 6 channels, two of them are alternatives: the IR3.74 channel works only during night, while the NIR1.6 channel works only during day.

The table below lists the names and the central wavelengths of the channels of the MetOp/AVHRR instrument and the central wavelength of the closest SEVIRI channels.

METOP/AVHRR channels		Closest METEOSAT/SEVIRI channel	
Name	Central wavelength	channel	Central wavelength
1	0.63	VIS0.6	0.64
2	0.87	VIS0.8	0.81
3a (daytime)	1.61	NIR1.6	1.64
3b (nighttime)	3.74	IR3.9	3.90
4	10.80	IR10.8	10.80
5	12.00	IR12.0	12.00

Day Microphysics RGB

Colour beam	Channel	Range			Gamma
Red	Channel 2	0	100	%	1
Green	Channel 3a	0	70	%	1
Blue	Channel 4	203	323	K	1

The table shows which channels are visualised in the red, green and blue colour beams. The measured values should be calibrated to calculate reflectivity (including also solar zenith angle correction) from the solar channels and brightness temperature from the thermal channel. The channels should then be enhanced – linearly stretched - within the brightness temperature and reflectivity ranges shown in the table. No gamma correction is applied.

Clouds RGB

Colour beam	Channel	Range			Gamma
Red	Channel 1	0	100	%	1
Green	Channel 2	0	100	%	1
Blue	Channel 4 inverted	323	203	K	1

The table shows which channels are visualised in the red, green and blue colour beams. The measured values should be calibrated to calculate reflectivity (including also solar zenith angle correction) from the solar channels and brightness temperature from the thermal channel. The channels should then be enhanced – linearly stretched - within the brightness temperature and reflectivity ranges shown in the table. No gamma correction is applied.

Natural Colours RGB

Colour beam	Channel	Range			Gamma
Red	Channel 3a	0	100	%	1
Green	Channel 2	0	100	%	1
Blue	Channel 1	0	100	%	1

The table shows which channels are visualised in the red, green and blue colour beams. The measured values should be calibrated to calculate reflectivity values (including also solar zenith angle correction). The images should be then enhanced – linearly stretched - within the reflectivity ranges shown in the table. No gamma correction is applied.

Night Microphysics RGB

Colour beam	Channel (difference)	Range			Gamma
Red	Channel 5 - Channel4	-4	+2	K	1
Green	Channel 4 - Channel 3b	-4	+6	K	1
Blue	Channel 4	243	293	K	1

The table shows which channels (or channel differences) are visualised in the red, green and blue colour beams. Before combining them, the measured values should be calibrated to calculate brightness temperatures. The channels (or channel differences) should be then enhanced – linearly stretched - within the brightness temperature ranges shown in the table. No gamma correction is applied.

VIIRS RGB recipes

The VIIRS instrument onboard of the NPP and NOAA-20 satellites has 22 bands. Some VIIRS RGBs serve as proxy data for the future MTG/FCI, as some VIIRS bands are not provided by SEVIRI but will be available for MTG/FCI.

In the VIIRS recipes below only the moderate (‘M’) resolution (750 m) VIIRS bands are used, as these channels are available through EUMETCast. However, the recipes are almost the same using the corresponding imagery (‘I’) resolution (375 m) bands.

Cloud Phase RGB

Colour beam	Channel		Range			Gamma
Red	M10	NIR1.61	0	50	%	1
Green	M11	NIR2.25	0	50	%	1
Blue	M5	VIS0.67	0	100	%	1

The Cloud Phase RGB is composed of the NIR1.61, NIR2.25 and VIS0.67 bands. The calibrated data should be enhanced – linearly stretched - within the reflectivity ranges shown in the table. Non-linear stretching is not needed.

Remarks:

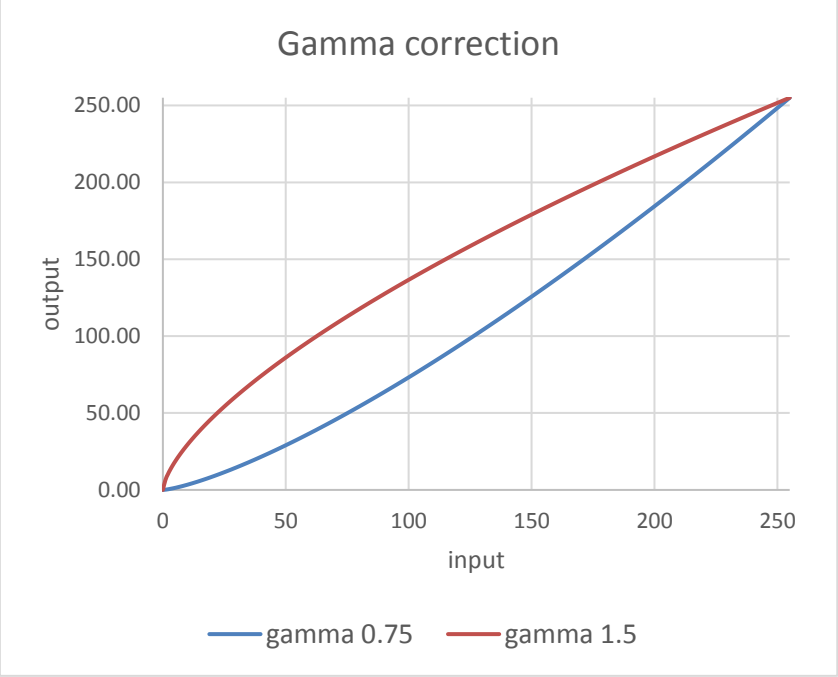
- This RGB type was invented by Jochen Kerkmann (EUMETSAT).
- It will become a standard RGB for the future FCI. (NIR2.25 is the channel which is not available in SEVIRI but FCI will measure within it.)
- The main aim is monitoring cloud top microphysics. It provides good cloud top phase identification for thick clouds.

Cloud Type RGB

Colour beam	Channel		Range			Gamma
Red	M9	NIR1.38	0	10	%	1.5
Green	M5	VIS0.67	0	80	%	0.75
Blue	M10	NIR1.61	0	80	%	1

The Cloud Type RGB is composed of the NIR1.38, VIS0.67 and NIR1.6 channel data. Before creating this RGB, the calibrated band data should be enhanced in two steps. First a linear stretch is performed within the indicated reflectivity ranges. Then the gamma correction is performed for the red and the green components.

The gamma correction performs non-linear expansion. It enhances the contrast either in the darker or in the brighter tones (depending on the Gamma parameter), and it makes the image darker or brighter. In case of the red and green components of the Cloud Type RGB (where Gamma is equal to 1.5 and 0.75), the contrast of the darker/brighter tones are increased, see the figure below.



Effect of the gamma correction if the Gamma parameter is 0.75 and 1.5

Remarks:

- This RGB type was invented by Andrew Heidinger (CIMSS).
- It may become a standard RGB for the future FCI. (NIR1.38 is the channel which is not provided by SEVIRI but FCI will provide it.)
- The main aim is to improve the detection of very thin cirrus clouds, first of all, over land and sea.

True Colour RGB

Colour beam	Channel		Range			
Red	M5	VIS0.67	0	110	%	piecewise linear stretching
Green	M4	VIS0.55	0	110	%	
Blue	M3	VIS0.49	0	110	%	

The True Colour RGB is composed of the VIS0.67, VIS0.55 and VIS0.49 bands.

To obtain good quality True Colour RGB images, one has to remove the Rayleigh scattering effects from the components, and perform a stretching, otherwise the image would be blurred; and the surface features would be too dark.

The Rayleigh scattering effect can be removed for example by the Polar2grid or Pytroll program packages. The enhancement could be done, for example in the same way, as it is suggested for MODIS images (https://cdn.earthdata.nasa.gov/conduit/upload/946/MODIS_True_Color.pdf).

- First a linear stretch is performed within the above indicated reflectivity ranges.
- Then a piecewise linear stretching is performed for all three components, according to the table below.

Input Brightness	Output Brightness
0	0
30	110
60	160
120	210
190	240
255	255

Non-linear Brightness Enhancement Table

The figure below shows the piecewise linear enhancement applied for the components. For comparison the gamma correction curves (with gamma equal to 1, 2 and 3) are also shown to demonstrate that these methods provide (similar, but) different non-linear stretching.

Piecewise linear enhancement compared to gamma correction curves (Gamma 1, 2 and 3)

Remarks:

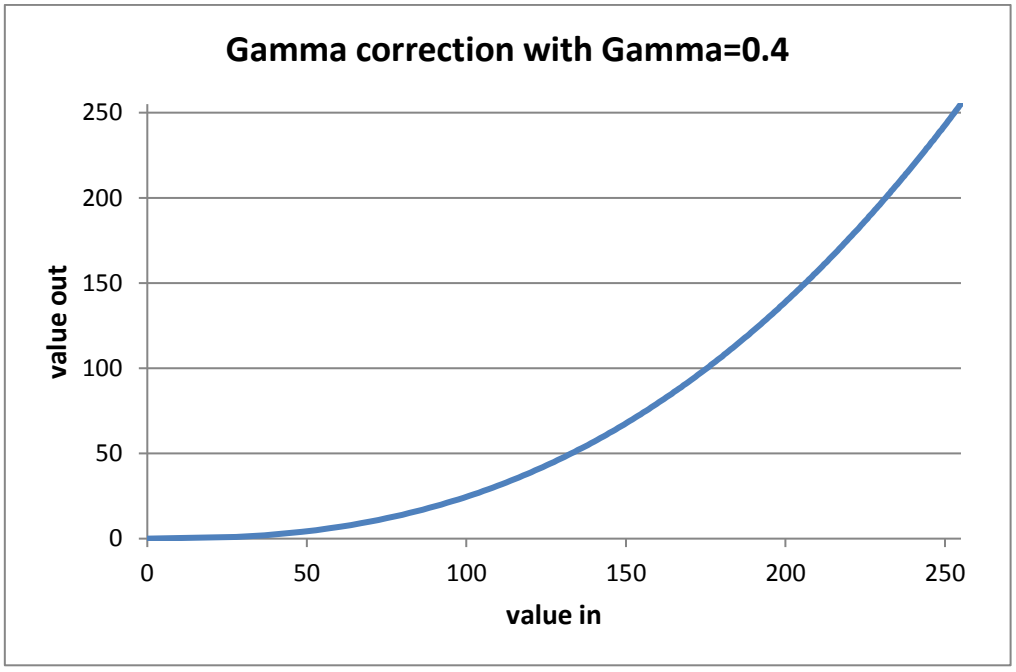
- It will become a standard RGB for the future FCI. (VIS0.55 and the VIS0.49 are the channels which are not available in SEVIRI but FCI will measure within it.)
- The main aims are aerosol monitoring and providing true colour images.

Fire Temperature RGB

Colour beam	Channel		Range			Gamma
Red	M12	IR3.7	273	333	K	0.4
Green	M11	NIR2.25	0	100	%	1
Blue	M10	NIR1.6	0	75	%	1

The Fire Temperature RGB is composed of the IR3.7, NIR2.25 and NIR1.6 channel data. Before creating this RGB, the calibrated band data should be enhanced in two steps. First a linear stretch is performed within the indicated brightness temperature and reflectivity ranges. Then the gamma correction is performed for the red component.

The gamma correction performs non-linear expansion. It enhances the contrast either in the darker or in the brighter tones (depending on the Gamma parameter), and it makes the image darker or brighter. In case of the red component of the Fire Temperature RGB (where Gamma is equal to 0.4), the contrast of the brighter tones are increased, see the figure below.



Effect of the gamma correction if the Gamma parameter is equal to 0.4

Night Microphysics RGB

Colour beam	Channel (difference)		Range			Gamma
Red	M16-M15	IR12.0 – IR10.8	-4	+2	K	1
Green	M15-M12	IR10.8 – IR3.7	-4	+6	K	1
Blue	M15	IR10.8	243	293	K	1

The table shows which channels (or channel differences) are visualised in the red, green and blue colour beams.

The channels (or channel differences) should be then enhanced – linearly stretched - within the brightness temperature ranges shown in the table. No gamma correction is applied.

Additional VIIRS RGBs

Additional VIIRS RGB recipes will be added later to this document:

- Day and Night Band combined with infrared image (the Day and Night Band is not available in SEVIRI data and will not available in FCI either)
- Natural Colour RGB
- Cloud RGB
- Day Microphysics RGB
- Dust RGB