Best practices for RGB compositing of multi-spectral imagery

Introduction

Until recently imagers on geostationary satellites were limited to 2-3 spectral channels, i.e. VIS, IR (and WV). Imagers on satellites in polar orbits offered a couple of additional channels, e.g. 3.9 micron and split window. The duty forecaster was used to look at such images in black-and-white rendering or through colour look-up tables enhancing particular features, typically cold clouds. Already at this point many schemes exist for displaying the imagery, and interpretation is sometimes difficult when not being acquainted with the particular colouring.

RGB compositing vs. classification

The advent of true multi-spectral imaging in geostationary orbit is offering increased insight into cloud and air mass characteristics. On RGB displays some of these characteristics may be easily evidenced with a minimum of processing by attributing a selection of channels and/or channel differences to the individual RGB colour planes. Such RGB composites convey very useful additional information to duty forecasters, in particular when looking at animated image sequences. Besides processing on the fly another advantage of RGB compositing (as opposed to more sophisticated processing using classification algorithms) is that the images preserve the "natural" look-and-feel of "traditional" satellite images, e.g. they preserve texture and patterns are continuous in time. Any classification scheme tends to flatten texture (down to chessboard-like patterns and mis/unclassified fringes) and to introduce temporal inconsistencies. These defects hamper reliable interpretation in an operational environment. In particular image sequences are not sufficiently smooth when animated, so important for the appraisal of dynamical aspects.

Objectives of RGB compositing

In the multi-spectral imager era RGB composites are an excellent addition to the tools available at the forecasters' bench. In an operational environment it is important of course, to judiciously select the RGB composites and limit their number to a strict minimum in accordance with the problems at hand. At the same time one should strive for composites being available night and day (i.e. IR only) and maximising feature identification. Depending of the particular multi-spectral imager RGB composites may support the identification of:

- solid and liquid water particles (snow – ice crystals – cloud droplets) and of their relative size at, close to, the cloud tops;
- weak-moderate and strong convection;
- dust and smoke plumes;
- air mass type in middle and high troposphere;

- evolution of snow cover and vegetation.

Limited colouring choices

Unlike classification algorithms coupled to colour look-up tables that allow for arbitrary feature colouring, RGB compositing cannot attribute specific colours/tints to specific features. However, colouring can be influenced by proper enhancement of the channels or their differences, and through rotation among the RGB colour planes. I.e. even when lacking arbitrary colour attribution RGB compositing offers a multitude of possibilities depending on the chosen channel (difference) combinations and on their attribution to the individual colour planes.

A note of caution is necessary, however. The colour/tint perception of the human eye may vary considerably from person to person. Even a slight colour deficiencies leads to a remarkably different colour perception. In other words, the safest way to display images remains the black-and-white rendering, though it is much less versatile.

A case for standardisation

So far no general standards have been set for channel (difference) selection, attribution to colour planes and appropriate enhancement. With the spreading of operational multi-spectral imagers it would be advisable to set some standards now, though there certainly will be further evolution. Such standards would contribute to WMO Space Programme's recommendation to strive for comparable data sets and products among satellite operators. In practical terms standardisation would coordinate worldwide training efforts and the work of duty forecasters as well as the exchange of information and procedures.

In Appendix A a minimum set of standard RGB composites is proposed. They are based on considerable experience with the MSG imager SEVIRI. The standards address identification of features listed above and are expressed in terms of combinations of channels or channel differences, attribution to the RGB colour planes and enhancement. The image manipulations refer to bidirectional reflectance factor values (BRF) for solar channels and equivalent brightness temperature values (EBT) for infrared channels. The enhancement operations expand to the full range of display values (0-255, BYTE) a limited range (MIN, MAX) of BRF[1] or EBT values, applying subsequently a gamma correction[2] (GAMMA) for possible non linear expansion:

$$BYTE = 255 * \left[\frac{\langle BRF, EBT \rangle - MIN}{MAX - MIN} \right]^{1/GAMMA}$$

Other, slightly deviating schemes for other imagers (AVHRR, MODIS, VIIRS, …) might be added in further appendices after Appendix C.

Appendix B floats the idea of combining the SEVIRI High Resolution Visible (HRV) imagery with RGB composites. Appendix C shows for SEVIRI the comparable set of MODIS channels.

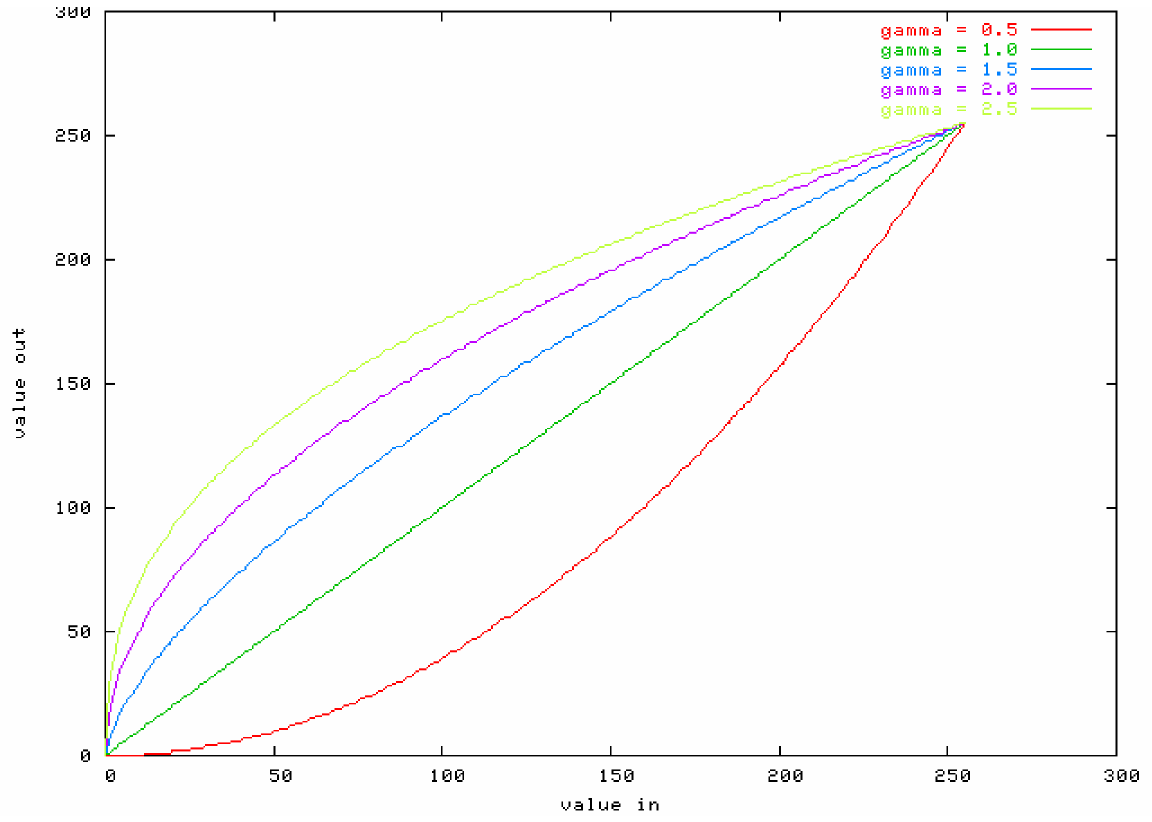
Notes:

[1] Use of BRF values for the solar channels implicitly compensates sun angle attenuation close to dawn/dusk

$$BRF = \frac{\pi * RAD * BW * SE^2}{SI * \cos(SZA)}$$

where Bidirectional reflectance factor BRF in [-], range 0 to ≥ 1
Radiance RAD in [W/(m^2*sr*µm)]
Sun-Earth distance SE in [AU]
Sun zenith angle SZA in [°]
Solar irradiance SI in [W/m^2]
Channel bandwidth BW in [µm])

[2)] The gamma correction changes the linear spreading of a selected range of pixel values over the full intensity scale to a convex (GAMMA < 1) or concave (GAMMA> 1) curve. I.e. the gamma correction enhances the contrast of the higher or lower parts of the pixel values in an image, respectively. In the RGB composites proposed here GAMMA is ≥ 1, i.e. contrast gets increased in the darker image parts.



Additional notes

- Annex A and B give the details of the recommended RGB composites for the SEVIRI imager. Other existing (e.g. AVHRR, MODIS) or future multi-spectral imagers with similar characteristics may use this information as templates. As an example Appendix C compares the SEVIRI channels to appropriate MODIS channels.
- Though somewhat more elaborate than the proposed RGB composites, MODIS has a true-colour scheme. It appears to be tuned rather to land cover issues than to the identification of meteorological phenomena.

- There is no proposal for an RGB composite specifically tuned to monitoring volcanic ash plumes. However, enhanced HRV (day only) or IR channel differences (e.g. 8.7µm - 10.8µm) may serve the purpose very well, though each volcano has its own chemical fingerprint as regards gas and ash release.
- More to the sample imagery is found in the Image Library on the EUMETSAT website.

Annex A

Proposed standard RGB composites – SEVIRI based

The following tables show a limited set of RGB composites proposed as standards (for SEVIRI, at least). The choice tries to offer a good spread of meteorological feature identification and as much 24 hours/7 days coverage as possible, be it is using pure IR schemes for 24-hour coverage, or having a day and night variant. For communication purposes the individual RGB composites are given reasonably meaningful names.

AIR MASS (night & day)					
RGB colour plane	channel (difference)	MIN	MAX	GAMMA	Prominent features
R	6.2 - 7.3	-25 K	0 K	1.0	(Rapid) cyclogenesis, jet streaks PV analysis Mid-level/high clouds
G	9.7 - 10.8	-40 K	+5 K	1.0	
B	6.2 (inverted!)	243 K	208 K	1.0	

DUST (night & day)					
RGB colour plane	channel (difference)	MIN	MAX	GAMMA	Prominent features
R	12.0 - 10.8	-4 K	+2 K	1.0	Dust (over land) Thin Ci Contrails
G	10.8 - 8.7	0 K	+15 K	2.5	
B	10.8	261 K	289 K	1.0	

NIGHT MICROPHYSICS					
RGB colour plane	channel (difference)	MIN	MAX	GAMMA	Prominent features
R	12.0 - 10.8	-4 K	+2 K	1.0	Cloud analysis Fog / low stratus Thin Ci Contrails
G	10.8 - 3.9 1)	0 K	+10 K	1.0	
B	10.8	243 K	293 K	1.0	

DAY MICROPHYSICS, winter					
RGB colour plane	channel (difference)	MIN	MAX	GAMMA	Prominent features
R	0.8	0 %	100 %	1.0	Cloud analysis Convection, fog Ship trails, snow, fire
G	3.9 (solar part only)	0 %	25 %	1.5	
B	10.8	213 K	303 K	1.0	

DAY MICROPHYSICS, summer					
RGB colour plane	channel (difference)	MIN	MAX	GAMMA	Prominent features
R	0.8	0 %	100 %	1.0	Cloud analysis Convection, fog Ship trails, snow, fire
G	3.9 (solar part only)2)	0 %	60 %	2.5	
B	10.8	203 K	323 K	1.0	

NATURAL COLOURS					
RGB colour plane	channel (difference)	MIN	MAX	GAMMA	Prominent features
R	1.6	0 %	100 %	1.0	Ice/water clouds, fog, snow Dust (over ocean), smoke (Green) vegetation
G	0.8	0 %	100 %	1.0	
B	0.6	0 %	100 %	1.0	

Note:

1) The SEVIRI IR3.9 channel is influenced by CO_2 absorption. Comparable channels on MODIS and AVHRR are less influenced by CO_2 absorption and thus the MIN/MAX range should be shifted by -4 K.

Optional composites:

DAY SNOW-FOG, winter					
RGB colour plane	channel (difference)	MIN	MAX	GAMMA	Prominent features
R	0.8	0 %	100 %	1.7	Fog Low clouds Snow
G	1.6	0 %	70 %	1.7	
B	3.9 (solar part only)2)	0 %	30 %	1.7	

DAY CONVECTIVE STORMS					
RGB colour plane	channel (difference)	MIN	MAX	GAMMA	Prominent features
R	6.2- 7.3	-35 K	+5 K	1.0	Severe convection WV in/outflux
G	3.9 - 10.81)	-5 K	+60 K	0.5	
B	1.6 - 0.6	-75 %	25 %	1.0	

Notes:

1) The SEVIRI IR3.9 channel is influenced by CO_2 absorption (correction to be applied may be estimated from the brightness temperature differences of the SEVIRI IR10.8 and IR13.4 channels). Comparable channels on MODIS and AVHRR are less influenced by CO_2 absorption and thus the MIN/MAX range should be shifted by +4 K.

2) The solar part of SEVIRI IR3.9 channel may be obtained by deducing the thermal contribution to the radiance from the SEVIRI IR10.8 channel and applying the CO_2 correction mentioned in note 1. For clouds that are semi-transparent in the SEVIRI IR3.9 channel the extraction of the solar part is not valid.

Annex B

Improved spatial resolution of RGB composites through combination with HRV – SEVIRI based

Mixing the High Resolution Visible (HRV) SEVIRI channel with any of the day RGB composites above adds the composite's feature identification capability to the higher spatial resolution. Adding 60% of the HRV values to 40% of the individual RGB components and attributing the sums to the respective RGB planes preserves much of the higher (3-fold) spatial resolution while still showing (in somewhat darker shades) the RGB composite's colour scheme . This is the preferred way to the alternative one of attributing HRV to the RG colour planes and any normal channel (typically 1.6 micron or 10.8 micron) to the B colour plane.

Annex C

Comparable MODIS channel set for SEVIRI

SEVIRI channels			**MODIS channels**	
#	**Name**	**Band [μm]**	**#**	**Band [μm]**
1	VIS0.6	0.56-0.71	**1**	0.620-0.670
2	VIS0.8	0.74-0.88	**2**	0.841-0.876
3	NIR1.6	1.50-1.78	**6**	1.628-1.652
4	MIR3.9	3.48-4.36	**20**	3.660-3.840
5	WV6.2	5.35-7.15	**27**	6.535-6.895
6	WV7.3	6.85-7.85	**28**	7.175-7.475
7	IR8.7	8.30-9.10	**29**	8.400-8.700
8	IR9.7	9.38-9.94	**30**	9.580-9.880
9	TIR10.8	9.80-11.8	**31**	10.780-11.280
10	TIR12.0	11.0-13.0	**32**	11.770-12.270
11	IR13.4	12.4-14.4	**33**	13.185-13.485
12	HRV	0.4-1.1*		

* Approximate values (response of silicon wafer)