W O R L D   M E T E O R O L O G I C A L   O R G A N I Z A T I O N
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RGB EXPERTS AND DEVELOPERS WORKSHOP

HOSTED BY JMA, EUMETSAT and WMO

7-9 NOVEMBER 2017

TOKYO, JAPAN

WMO General Regulations

Regulation 42

Recommendations of working groups shall have no status within the Organization until they have been approved by the responsible constituent body. In the case of joint working groups the recommendations must be concurred with by the presidents of the constituent bodies concerned before being submitted to the designated constituent body.

Regulation 43

In the case of a recommendation made by a working group between sessions of the responsible constituent body, either in a session of a working group or by correspondence, the president of the body may, as an exceptional measure, approve the recommendation of behalf of the constituent body when the matter is, in his opinion, urgent and does not appear to imply new obligations for Members. He may then submit this recommendation for adoption by the Executive Council or to the President of the Organization for action in accordance with Regulation 9(5).

EXECUTIVE SUMMARY

The RGB[1] Experts and Developers Workshop 2017 was hosted by JMA, EUMETSAT, and WMO on 7-9 November 2017 in Tokyo, Japan, at JMA Headquarters. It was the third a series of RGB-related community events after 2007[2] and 2012[3] which resulted in widely-agreed RGB composite standards used in operations, training, and research. Main objective of the event was to review these standards in view of enhanced next-generation geostationary imagery, such as now available from Himawari-8 AHI and GOES ABI, and recognizing other advances in data, science and operational practice. The event had 32 participants from all six WMO Regions, and was organized in liaison with, and support to, the WMO-CGMS Virtual Laboratory on Education and Training in Satellite Meteorology (VLab).

The objectives of the workshop were:

- Review of existing RGB composite standards
- Application of RGBs using new-generation imagers
- Demonstrating the value of RGBs in context (NWP, products)
- Compilation of demonstration and training material
- Exploring new standards for satellite-based composites

Participants of the workshop agreed on Recommendations related to:

1. Adjustment and extension of existing RGB standards
2. Regional (e.g., tropical) variants of RGB composites
3. Proposals for new RGB standards
4. Other recommendations related to:
    - Renaming the Dust RGB into "24-hour Microphysics RGB – Dust Version" and the Ash RGB into "24-hours Microphysics RGB – Ash Version"
    - Limb correction factors for IR window channels
    - Communicating the gamma factor
    - Generation and use of training material
    - Transitioning RGBs into operations
    - Best practices for colour-impaired viewers

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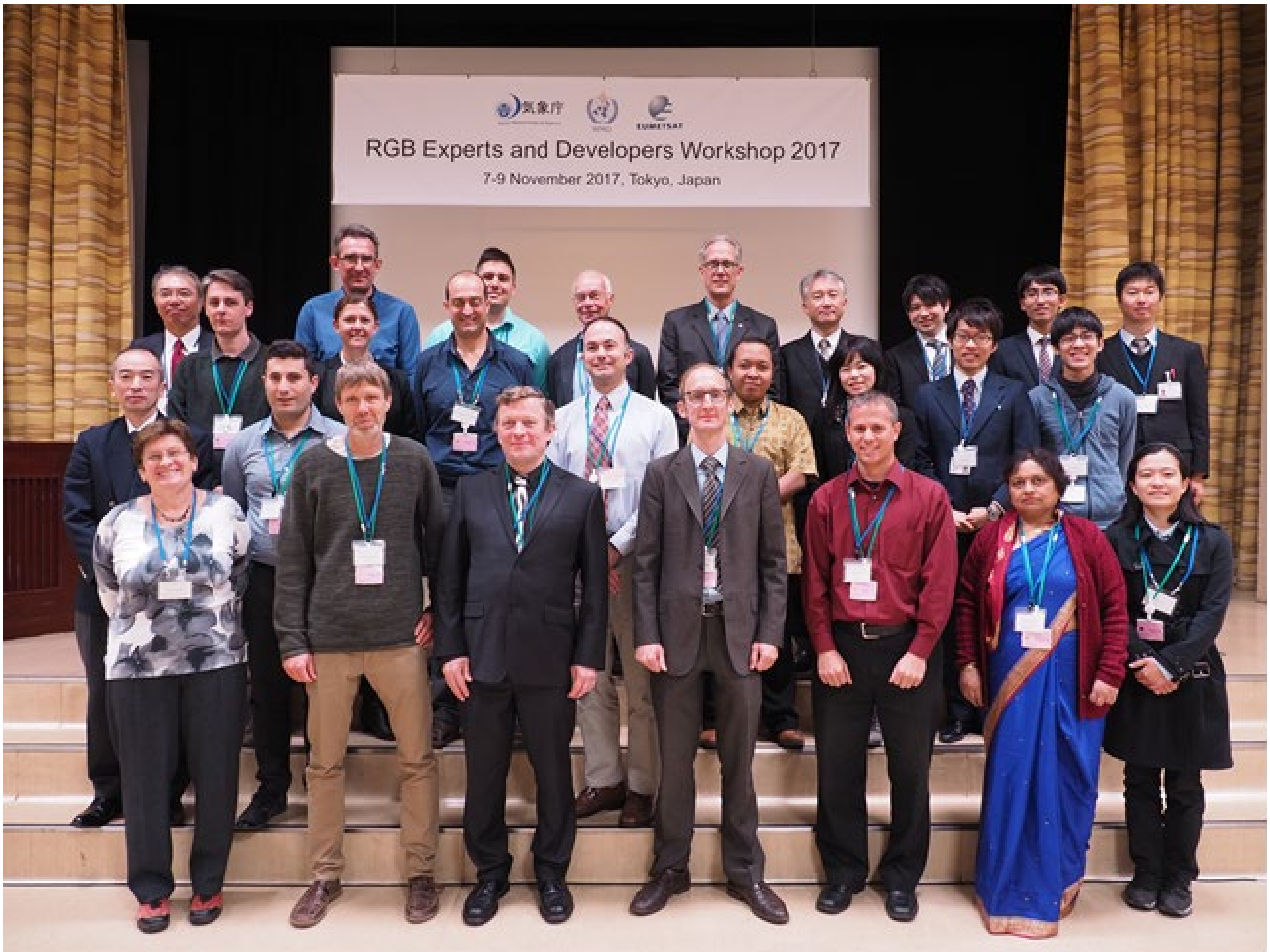
[1] RGB (Red-Green-Blue) satellite products (or composites) refer to satellite imagery with the information content of multiple spectral channels mapped against an RGB colour scheme, for optimized visualization while at the same time preserving pattern and texture of atmospheric (e.g., cloud) and surface features, as well as continuity over time.

[2] WMO (2007): RGB Composite Satellite Imagery Workshop, Final Report. Boulder, CO, USA, 5-6 June 2007, http://www.wmo.int/pages/prog/sat/documents/RGB-1_Final-Report.pdf

[3] WMO (2012): WMO/EUMETSAT Workshop on RGB Satellite Products, Final Report, Seeheim, Germany, 17-19 September 2012, http://www.wmo.int/pages/prog/sat/documents/RGB-WS-2012_FinalReport.pdf



From left to right:

Front Row: Maria Putsay, Jochen Kerkmann, Bodo Zeschke, Stephan Bojinski, Kevin Fuell, Suman Goyal, Sunmi Na

Second Row: Yasushi Suzuki, Celil Kaplan, Kevin McGrath

Third Row: Renato Galante Negri, Lee-ann Simpson, Jean-Baptiste Hernandez, Indarto Sugeng, Hye Sook Park, Yusuke Ioka, Yuki Takano

Fourth Row: Hitomi Miyamoto, Roland Winkler, Djordje Gencic, HansPeter Roesli, Gary Jedlovec, Motowo Hayashi, Akihiro Shimizu, Takumi Maruyama, Hidehiko Murata

Not in picture: Yuji Akasaka, Toshinori Aoyagi, Hyun-Ju Ban, Humberto Alves Barbosa, Jinlong Fan, Changbao Li, Ryuji Nagayama, Hiroaki Tsuchiyama

0. INTRODUCTION

The three-day workshop, jointly organized by JMA, EUMETSAT, and WMO, opened at 09.30 on 7 November 2017 at JMA Headquarters in Tokyo, Japan. It was the third a series of RGB-related community events after 2007[4] and 2012[5] which resulted in widely-agreed RGB composite standards used in operations, training, and research. Main objective of the 2017 workshop was to review these standards in view of enhanced next-generation geostationary imagery, such as now available from Himawari-8 AHI and GOES ABI, and recognizing other advances in data, science and operational practice. The event had 32 participants from all six WMO Regions (see list of participants in Annex I and the agenda in Annex II). It was organized in liaison with, and support to, the WMO-CGMS Virtual Laboratory on Education and Training in Satellite Meteorology (VLab).

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In his opening remarks, Naoyuki Hasegawa, Observing Department, JMA, expressed his satisfaction to host the workshop, together with WMO and EUMETSAT. A new generation of multispectral sensors was available onboard Himawari, FY and GOES satellites, and soon on MTG-I. Loops and animations using their imagery were impressive; in addition, RGBs offer an additional way to retrieve a maximum of information from satellite data. The development of RGBs and standards has been subject to international collaboration, and this should continue. In this regard, he stressed the importance of close collaboration with user communities such as operational forecasters, volcanic ash monitoring centres, and the private sector. He wished all participants a successful workshop, looking forward to new ideas and suggestions for new standards as a result.

Stephan Bojinski (WMO) thanked JMA for hosting and supporting the workshop, and EUMETSAT for their collaboration in supporting participation, and for organizing and shaping the agenda. He recalled the 2012 workshop results and their strong uptake by many satellite operators, VLab training centres, and users, and called for their review based on the new-generation capabilities. He stressed the substantial overlap in spatial and spectral coverage of the next-generation geostationary imagers, and called for exploiting synergies (aim of a SCOPE-Nowcasting Pilot Project) but also recognizing their differences when devising new RGB standards. The workshop should also look into recommendations for generating RGBs from existing and upcoming polar-orbiting imagers such as VIIRS and METimage.

Presentations and background documents were made available to participants on a dedicated meeting website hosted by WMO: http://www.wmo.int/pages/prog/sat/meetings/RGB-WS-2017.php

1. SESSION 1: REVIEW OF EXISTING RGBs (Chair: J. Kerkmann)

Jochen Kerkmann stressed the importance of the workshop for setting global standards which should be used all around the world in forecasting and training contexts; he pointed out the added value of RGBs for forecasters, for they sometimes reveal features that cannot be seen in quantitative products.

[4] WMO (2007): RGB Composite Satellite Imagery Workshop, Final Report. Boulder, CO, USA, 5-6 June 2007, http://www.wmo.int/pages/prog/sat/documents/RGB-1_Final-Report.pdf

[5] WMO (2012): WMO/EUMETSAT Workshop on RGB Satellite Products, Final Report, Seeheim, Germany, 17-19 September 2012, http://www.wmo.int/pages/prog/sat/documents/RGB-WS-2012_FinalReport.pdf

a) Hidehiko Murata, Akihiro Shimizu, JMA – Adjusting SEVIRI RGB recipes for AHI

JMA investigated Spectral Response Function (SRF) differences between AHI and SEVIRI, e.g., MSG CH09 (10.8µm) and AHI B13 (10.4µm). Mr Murata looked at a recipe adjustment method for the Night Microphysics RGB and the Airmass RGB using AHI imagery, using pseudo data from IASI convolved over the SRFs and compared the datasets in the overlap region of AHI and Meteosat-8 SEVIRI Indian Ocean Data Service.

The proposed adjustments are as follows:

Adjustment of **Night Microphysics RGB for AHI**:

From:

RGB	MSG Channels	Central wave length [µm]	Min [K]	Max [K]	Gamma
R	CH10-CH09	12.0-10.8	-4	2	1.0
G	CH09-CH04	10.8-3.9	0	10	1.0
B	CH09	10.8	243	293	1.0

To:

RGB	AHI Bands	Central wave length [µm]	Min [K]	Max [K]	Gamma
R	B15-B13	12.3-10.4	-7.5	3.0	1.0
G	B13-B07	10.4-3.9	-2.9	7.0	1.0
B	B13	10.4	243.7	293.2	1.0

J. Kerkmann commented that the best channel combination for the Green beam needs investigating.

Adjustment of **Airmass RGB for AHI:**

From:

RGB	MSG Channels	Central wave length [µm]	Min [K]	Max [K]	Gamma
R	CH05-CH06	6.2-7.3	-25	0	1.0
G	CH08-CH09	9.7-10.8	-40	5	1.0
B	CH05	6.2	208	243	1.0

To:

RGB	AHI Bands	Central wave length [µm]	Min [K]	Max [K]	Gamma
R	B08-B10	6.2-7.3	-25.8	0	1.0
G	B12-B13	9.6-10.4	-41.5	4.3	1.0
B	B08	6.2	208	242.6	1.0

b) Jochen Kerkmann, EUMETSAT - Tropical versions of the Airmass, Night Microphysics and Convection RGBs

The original Airmass RGB was conceived for mid-latitudes, not for tropical regions. Tropical convective clouds have higher optical depths (white) and are generally much colder. The standard Airmass RGB saturates over clouds, whereas the new proposed RGB makes the most active convective areas more visible. Some water vapour features may not be as visible, therefore both RGB schemes should be used in parallel. He presented a draft recipe for the tropical Airmass RGB.

The Night Microphysics RGB and Convection RGB were also adjusted for tropical areas, enabling better contrast of low-level clouds (e.g., fog in river valleys) and enhanced detection of fires for the former, and better contrasting overshooting tops for the latter.

In total, three tropical RGBs were tuned to colder cloud tops, higher moisture and temperature, and implemented in McIDAS-V. They are used in some African countries, following a training event. Fog detection is strongly dependent on spatial resolution.

The need to come up with recommendations for tropical adaptations of the AHI-adjusted versions was identified (Bodo Zeschke, Jochen Kerkmann and Akihiro Shimizu to investigate).

Adjustment of SEVIRI Airmass RGB for Tropical Areas:

From:

RGB	MSG Channels	Central wave length [μm]	Min [K]	Max [K]	Gamma
R	CH05-CH06	6.2-7.3	-25	0	1.0
G	CH08-CH09	9.7-10.8	-40	5	1.0
B	CH05	6.2	208	243	1.0

To:

RGB	MSG Channels	Central wave length [μm]	Min [K]	Max [K]	Gamma
R	CH05-CH09	6.2-10.8	-25	5	1.0
G	CH08-CH09	9.7-10.8	-30	25	0.5
B	CH05	6.2	190	243	1.0

Adjustment of SEVIRI Convection RGB for Tropical Areas:

From:

RGB	MSG Channels	Central wave length [μm]	Min []	Max []	Gamma
R	CH05-CH06	6.2-7.3	-35 K	5 K	1.0
G	CH04-CH09	3.9-10.8	-5 K	60 K	0.5
B	CH03-CH01	1.6-0.6	-75%	25%	1.0

To:

RGB	MSG Channels	Central wave length [μm]	Min []	Max []	Gamma
R	CH05-CH06	6.2-7.3	-35 K	5 K	1.0
G	CH04-CH09	3.9-10.8	-5 K	75 K	0.33
B	CH03-CH01	1.6-0.6	-75%	25%	1.0

Adjustment of SEVIRI Night Microphysics RGB for Tropical Areas

From:

RGB	MSG Channels	Central wave length [μm]	Min [K]	Max [K]	Gamma
R	CH10-CH09	12.0-10.8	-4	2	1.0
G	CH09-CH04	10.8-3.9	0	10	1.0
B	CH09	10.8	243	293	1.0

To:

RGB	MSG Channels	Central wave length [μm]	Min [K]	Max [K]	Gamma
R	CH10-CH09	12.0-10.8	-4	2	1.0
G	CH09-CH04	10.8-3.9	0	5	1.0
B	CH09	10.8	273	300	1.0

c) Jean-Baptiste Hernandez, Météo-France: RGB multichannel colour composite images at Météo-France

Météo-France have developed a dual approach to RGBs for forecasting, one RGB for daytime and one for nighttime. The choice of colours comes first (high cloud: turquoise etc.) based on sensitivity of the human eye to colours and contrast, experience with MSG, and usage by forecasters for over 15 years. A combined Day&Night RGB is generated by calculating pseudo-channels for the RGBs, tuning. They developed adaptions for different sensors (FY-2G AGRI, Himawari-8 AHI, AVHRR), and use new channels to adapt to new sensors. Such RGBs use most channels, with fixed colours during day and night. This is similar to the GeoColor approach by U.S. groups.

d) HansPeter Rösli, Invited Expert, Switzerland: Detection of thin low aerosol plumes with fine-tuned Dust RGB

This investigation was triggered by a DLR research flight over the Eastern Mediterranean in smoke and dust-polluted air. Varying ranges of Equivalent Blackbody Temperature (EBBT) enhance the contrast of dust over the ocean. Thin low-level dust over ocean is hard to detect. Combining HRV and the standard Dust RGB is useful.

Detection of low-level dust over land is very challenging.

Discussion

Kevin Fuell asked for clarification about the new or adjusted standard reference, using new-generation imagery. Future MTG FCI imagery needs to be taken into account as well.

The naming of some standard RGB schemes may need changing, e.g., the Dust RGB is useful for detecting humidity gradients.

The Application Areas of RGB composites remain the same.

Many participants agreed that the colour assignment in RGB composite should not change significantly (for not to lose the build-up of skill, training material, etc.).

Multi-panel display of forecasters helps catching features (usually 4 panels), including animation
How to address colour blindness of users?

Shortcomings of current RGBs are recognized in polar, dry air (e.g., in SEVIRI imagery over Siberia).

Bodo Zeschke observed that Tropical RGBs were performing better in many/all respects.

Jochen Kerkmann remarked that the lower ranges in Convection RGBs in polar regions (Alaska, Finland) were particularly significant.

Imagery over the Maritime Continent (Indonesia and neighbouring states), with high moisture content at different levels, has its own challenges.

2. SESSION 2: NEW RGBs BASED ON NEWLY-AVAILABLE CHANNELS IN GEO (Chair: A. Shimizu)

a) Akihiro Shimizu, Yusuke Ioka, JMA: New RGBs by using of AHI imagery

Mr. Shimizu presented new proposals for RGBs using AHI imagery. He argued that the new RGBs have possibilities of

i) visualization of atmospheric conditions (simple and differential water vapour RGBs)
ii) better estimation of cloud phase (water/ ice), and
iii) possibility to detect SO_2 gas (cases for Japan, Kamchatka).

The cloud phase composite showed some evidence for better phase distinction, however it is not consistent with the existing Day Cloud Microphysics RGB standard.

It was recommended not to deviate from the existing standard. More generally, J. Kerkmann pointed out that consideration of other similar RGB containing same bands/channels would be required to develop new RGBs.

b) Sunmi Na, KMA: Discriminating snow and ice clouds

Dr. Na introduced a new snow-covered area distinction approach by using the time differential of one hour ago and present. Dr. Park mentioned the difficulty of distinction due to similar colour appearance of high clouds (containing ice crystals) and snow-covered area in the Natural

Colour RGB. The proposed experimental product uses spatial and temporal variability of snow and cirrus; thresholds introduce jumps that are due to classifications at the edge of products and RGBs. Some good distinction was shown, and improvement of Natural Colour RGB.

Regarding the observed jumps, HP Rösli mentioned that the original logic behind RGBs has been their smoothness over time. J.-B. Hernandez remarked that introducing the 2.3μm channel into generating snow products has led to improvements.

c) Sunmi Na, KMA: Improvement of Dust RGB with AHI

Dr. Na showed results of an investigation to improve the Dust RGB using AHI data. The proposed recipe applies a differential image of 10.4-13.3μm to the Blue beam, instead of the 10.4 microns band only (see session 1a). She introduced some cases of dust outbreaks over East Asia. In cooler regions, i.e., higher Northern latitudes, the modified RGB has better contrast and allows for better distinction between clear and cloudy regions.

The proposed improvement to the Dust RGB for AHI looks as follows:

RGB	Original	Modified
R	IR12.3-IR10.4	IR12.3-IR10.4
G	IR10.4-IR8.6	IR10.4-IR8.6
B	IR10.4	IR10.4-IR13.3

J. Kerkmann commented that for the Dust RGB, the AHI Green band 11.2-8.6μm differential was better suited than 10.4-8.6μm for the depiction of cloud physics.

d) Maria Putsay, Hungarian Meteorological Service: Experiences with the Himawari Cloud Phase RGB

Dr. Putsay presented an investigation of distinguishing cloud phase using 1.6 and 2.3μm imagery, using examples from AHI for tropical cyclones near Australia and China. Telling water clouds from ice clouds depends on effective radius of particles; it is easier for large and more difficult for small r_eff. She proposed a novel cloud phase RGB, based on the 2.3μm (most sensitive to particle size), 1.6μm (most sensitive to phase) and 0.47μm (sensitive to optical depth) bands (see item 2g). The effects of very thin ice clouds over thick water clouds in 2.3μm band were also analysed.

Jochen mentioned about the usefulness of the combination of 1.6 and 2.3 microns images for cloud phase distinction on this RGB.

e) J.-B. Hernandez, Météo-France: New Météo-France products using Himawari-8 AHI and GOES-16 ABI data

Mr. Hernandez introduced new RGBs (Day RGB and Night RGB) generated by Météo-France by using ABI and AHI data. This works aims at smooth transition within an image from day to night, since many features change their appearance. He indicated that VIIRS/Suomi-NPP data will be a good reference for ABI and AHI. These RGBs are created by an advanced algorithm, however the colour displaying is very simple and user-friendly. Regarding the colour selection, the discussion about consideration for colour-blinded was done. He noted that overlay of geostationary and polar-based RGBs was more useful in the development process, rather than in a forecaster environment (except perhaps in high latitudes).

f) Jochen Kerkmann, EUMETSAT: The dilemma of four IR window channels – tuning of the Dust RGB to ABI / AHI

J. Kerkmann introduced the respective specifications of differential combinations by four IR channels of ABI/AHI (12.4, 11.2, 10.4, 8.6μm). When applied to Dust/Ash RGBs, the 12.4-10.4μm differential seems to be best for the Red component (better moisture and thin cirrus detection), and 11.2-8.6μm appears best for the Green component (for example, for cloud phase distinction compared to the 10.4-8.6μm differential). For detecting volcanic ash, he compared the brightness temperature difference (BTD) 12.4-10.4μm with 12.4-11.2μm: in a Kamchatka case, the former performed better; in a case with cirrus clouds and high moisture (Indonesia volcanic eruption), the latter performed better.

MTG FCI does not have a 11.2μm channel, and it is recommended to use the 12.4μm for the purpose of the Dust/Ash RGB.

He additionally mentioned that the original name of the Dust and Ash RGBs were 24-h Microphysics RGB.

g) Jochen Kerkmann, EUMETSAT: New RGB products from MTG FCI

Dr. Kerkmann introduced the future RGBs for MTG FCI. FCI will have new solar channels such as 0.96, 2.25, 0.444 and 1.375μm. The new RGBs contain these new channels and he emphasized their usefulness; tested and implemented using proxy data currently are:

True colour RGB (for media and outreach purposes mainly):

RGB	FCI Channels	Central wave length [μm]	Min [%]	Max [%]	Gamma
R	VIS0.6	0.64	0	100	1.0
G	VIS0.5	0.51	0	100	1.0
B	VIS0.4	0.44	0	100	1.0

Cloud phase RGB:

RGB	FCI Channels	Central wave length [μm]	Min [%]	Max [%]	Gamma
R	NIR1.6	1.6	0	50	1.0
G	NIR2.3	2.3	0	50	1.0
B	VIS0.5 / VIS0.6	0.5 / 0.6	0	100	1.0

Fire temperature RGB:

RGB	FCI Channels	Central wave length [μm]	Min []	Max []	Gamma
R	IR3.9	3.9	273 K	350 K	1.0
G	NIR2.3	2.3	0 %	50 %	1.0
B	NIR1.6	1.6	0 %	50 %	1.0

Ideas for new RGBs are:

- Cloud type RGB using the NIR1.3μm band (on ABI as well) – useful for detecting high-level clouds and other features; thick ice clouds, thin cirrus clouds.
- Day Microphysics RGB (with NIR2.25μm)

Particularly, he mentioned that the 1.375μm channel will be very effective to distinguish water and ice clouds using cloud height information.

He advocated exploring a Moisture RGB using the 0.9 and 0.8μm channels (MODIS proxy data only), to detect low-level moisture. Lee-Ann Simpson asked whether 7.3μm channel was also effective to capture moisture – Jochen Kerkmann pointed out that this channel is mostly sensitive to upper-level moisture.

Discussion

Some discussion evolved around terminology for RGBs. For example, re-naming the Dust RGB '24-h Microphysics – Dust Version RGB'.

3. SESSION 3: RGBS BASED ON LEO IMAGERS, OTHER SENSORS (Chair: M. Putsay)

a) Kevin McGrath, NASA SPoRT: Application of LEO RGBs to Polar and Tropical Regions

The situation of Alaska favours the use of polar-orbiting imagery for forecasters in that region (MODIS, AVHRR, VIIRS), using direct readout and CSPP software for processing. These data were used to prepare forecasters for using Himawari-8 AHI and GOES ABI. The new U.S. NWS display system allows developers to expand capabilities (AWIPS-II). NASA SPoRT developed a client-side RGB capability based on standards recipes, and applied it to SEVIRI, AHI, ABI. Tropical applications include the Day-Night band from VIIRS. GPM GMI data are used to provide a rain rate product. VIIRS and CrIS channels are used to produce an Airmass product.

RGBs using MW imagery and also MW soundings have gained traction in some situations, e.g. tropical cyclones.

b) Celil Kaplan, Turkish State Meteorology Service: Sentinel-3 RGBs and MSG RGBs comparison regarding spatial resolution needs

C. Kaplan used Sentinel-3 Sea and Land Surface Temperature Radiometer (SLSTR) and Ocean and Land Colour Instrument (OLCI) data to create RGBs and compared them with MSG data over SE Europe and Turkey / Middle East. He also compared cloud mask dependence on spectral resolution. Many RGBs from SLSTR appeared rather dark, possibly due to lack of pre-processing.

Maria Putsay noted that performing the solar zenith angle correction for shortwave channels might help to get more bright colours. She noted as well that for polar satellite data the viewing geometry is different than for GEO satellite data and this has also an effect on the colours.

c) HansPeter Rösli, Invited Expert, Switzerland: Detection of exotic cloud phases with VIIRS RGBs

He showed investigations of cloud top phases just above and below freezing point, over Arabian peninsula, using VIIRS data (cloud phase RGB); this helps distinguishing supercooled and frozen cloud tops. Sometimes medium to large droplets have the same effect on colour (cyan) as ice clouds. He also compared VIIRS and AHI for cloud phase and volcanic ash. Some small cumulus clouds over the Arabian peninsula possibly generated by salt particles from the Arabian sea.

K. Fuell asked what RGB recipe adjustments are suggested for the various LEO imagers (VIIRS, Sentinel-3, eventually METImage).

Bodo Zeschke asked why the droplets of small Cu clouds over desert could be large. Jochen Kerkmann said that close to the coast the sea-breeze can bring moist maritime air over land. He noted as well that identification of supercooled clouds or warm rain clouds is important.

He commented that the NIR1.3 channel is good for monitoring several high-level features, like thin cirrus clouds, hurricane monitoring etc.

4. SESSION 4: APPLICATION EXAMPLES OUTSIDE MSG 0° FOOTPRINT (Chair: B. Zeschke)

a) Bodo Zeschke, Australian Bureau of Meteorology: AHI RGB products and modifications as applied over the Australia-Pacific regions with relevant case studies: the Australian VLab Centre of Excellence Experience

He showed examples of the Night Microphysics and Day Convective RGB over Darwin (Australia): mid-latitude vs tropical adjusted (JMA), as well as a local variant (tuning in Red and Green beams). The Day Convective RGB was used to study tropical cyclone Blanche; it uses more channels and takes more time to load than the Sandwich product. The Day Microphysics RGB is very popular among forecasters to distinguish surface and cloud features, and cloud structures. The Dust RGB was used to study dust outbreaks in Australia: moist low- to mid-levels can hide dust signal; multi-panel display can help forecasters to have an overview.

Engagement by the Australian VLab Centre has helped support focus group sessions in WMO Regional Association V (South-West Pacific), leading to substantial capacity build-up in the use of RGBs for example in Indonesia and Singapore.

b) Kevin Fuell, NASA SPoRT: Transition and Application of SEVIRI-based RGB recipes to GOES-16

NASA SPoRT supported the NOAA/NWS Operations Proving Ground and brought in H-8 AHI imagery to gain insight which GOES-16 ABI channels would provide most operational value to forecasters. Both Applications training, Foundational training (for less known or less intuitive RGBs) were considered important with respect to RGBs. Local and regional applications examples needed to be developed.

The Dust RGB allowed for an operational change to issue Dust Advisories by NWS (outbreaks in Mexico, border U.S.-Canada).

The Nighttime Microphysics RGB was applied to both LEO and GEO, and proved very useful for detecting low clouds and fog for aviation forecasts.

The Airmass RGB is in regular use for monitoring air masses, inferring cyclogenesis, and regularly featured in forecasting and social media posts. It has been extensively used at U.S. national weather centres to prepare for GOES-16 ABI.

All RGBs are available to U.S. forecasters; training within a Foundational Course is needed since most users are inexperienced in operations.

Update of the RGB Best Practices is required. Compiling a Best Practices document on how RGBs were transitioned and introduced to users is planned, based on experience with RGB transition practices:

1. Identify need where RGB may have impact or provide greater efficiency
2. Select small group of operational users for “Trial” of RGB
    - Provide supporting training and past examples to demonstrate benefit
3. Gather feedback from users that

shape the transition of RGB to larger operational audience

- Modify product, training, or display properties based on feedback.

4. Collaborate to take users to next level of RGB understanding and application
    - Secondary applications, special cases
    - More details to answer “why?” questions

c) Jochen Kerkmann, EUMETSAT: New features discovered in RGBs outside the MSG (Meteosat-10) footprint (smoke, snow/ice etc.)
He showed a range of features worth investigating in RGBs, mostly based on SEVIRI data collected by the Indian Ocean Data Service. Dust / Ash RGB reveal details of dust outbreaks in Mongolia and Central China, Argentina, Pakistan. The Dust RGB applied to AHI allows for delineation of moisture boundaries. Heavy convective systems or supercells should be analysed using high-resolution visible imagery (500mHR), together with RGBs (2km HR).

The Ash RGB shows volcanic ash and SO_2 in volcanic plumes over Kamchatka in AHI imagery. The Dust RGB produces special colours of sandy surface (Northern China). Very cold land surfaces (snow) e.g., over Siberia, have a strong signature in the Airmass RGB which is not visible in Central Europe. The Natural Colour RGB shows an example of frozen Lake Baikal. The Night Microphysics RGB performs well in identifying fog and low clouds. The Convection RGB shows high supercooled clouds over the tropical Atlantic and Australia.

d) Djordje Gencic, Serbia: Volcanic eruptions seen in RGB images.
He showed application of the Dust / Ash RGB to AHI imagery in the East Asia region (‘ring of fire’).

Discussion

Participants noted that when applied around the world, the application of RGB recipes has more commonalities than differences, never mind regional differences.

Roland Winkler noted that lee wave clouds can cause incidents of aircraft icing at relatively low levels (3000-3200m?), due to supercooled droplets – can these be detected?

5. SESSION 5: INTERCOMPARISONS OF GEO RGBs IN OVERLAP REGIONS (Chair: J. Kerkmann)

a) Gary Jedlovec, NASA SPoRT: Limb Correction and Adjustments Applied to Imagery Derived from Differing Sensors to Improve Comparisons of RGBs

Differences in brightness temperature between two sensors can be attributed to differences in band spectral response in overlap areas. Limb effects can also play a role towards the edge of sensor field-of-view. An offset correction is proposed for collocated nadir points and over a homogeneous surface (cloud-free ocean scene), as well as a limb correction. SEVIRI proxy data based on VIIRS or MODIS are calculated using the offset correction. The corrections were tested with the Dust RGB.

Points to retain:

- Consider impact of sensor-specific recipes to end users;
- Document and share recipe adjustments for RGBs and sensor types;
- Set standards for decimal precision when specifying min/max values and communication of gamma variable or exponent.

In this study, emission channels only were considered since these are easier to handle, rather than scattering channels (more complex to simulate and correct sensor radiances and their differences).

b) Roland Winkler, Austro Control: Similarities and Differences between MSG SEVIRI and Himawari AHI RGBs

He investigated differences for RGBs between the two imagers in the overlapping area above the Indian Ocean. There are some differences in the channels SRF, and some differences in available channels. For example, availability of the microphysical channel 2.3 µm in combination with NIR1.6 µm is a huge benefit for cloud phase analysis. Differences are noticeable for 24h Microphysics RGB, Night Microphysics RGB, and the Dust RGB. The AHI channel 3.9 µm seems to be less stable at cold temperatures than MSG. Differences are negligible for the Airmass RGB Phase, Severe Convection RGB, and Day Natural Colour RGB.

The proposed variant of the '24-hour Microphysics – Cloud version' RGB for AHI is as follows:

RGB	MSG Channels	Central wave length [µm]	Min [K]	Max [K]	Gamma
R	CH10-CH09	12.0-10.8	-4	2	1.0
G	CH09-CH07	10.8-8.7	0	6	1.2
B	CH09	10.8	248	303	1.0

RGB	AHI Bands	Central wave length [µm]	Min [K]	Max [K]	Gamma
R	B15-B13	12.4-10.4	-4	2	1.0
G	B14-B11	11.2-8.6	0	6	1.2
B	B13	10.4	248	303	1.0

The proposed variant to the Night Microphysics RGB for AHI is as follows (cf paper 1a by H. Murata which also proposed such modifications):

RGB	MSG Channels	Central wave length [µm]	Min [K]	Max [K]	Gamma
R	CH10-CH09	12.0-10.8	-4	2	1.0
G	CH09-CH04	10.8-3.9	0	10	1.0
B	CH09	10.8	243	293	1.0

RGB	AHI Bands	Central wave length [µm]	Min [K]	Max [K]	Gamma
R	B15-B13	12.4-10.4	-6.7	2.6	1.0
G	B13-B04	10.4-3.9	0	6	1.0
B	B13	10.4	243.6	292.6	1.0

The proposed variant to the Dust RGB for AHI is as follows:

RGB	MSG Channels	Central wave length [μm]	Min [K]	Max [K]	Gamma
R	CH10-CH09	12.0-10.8	-4	2	1.0
G	CH09-CH07	10.8-8.7	0	15	2.5
B	CH09	10.8	261	289	1.0

RGB	AHI Bands	Central wave length [μm]	Min [K]	Max [K]	Gamma
R	B15-B13	12.4-10.4	-4	2	1.0
G	B14-B11	11.2-8.6	0	10	2.5
B	B13	10.4	261	289	1.0

A Natural Colour RGB was not further pursued: for MTG with similar channels than Himawari, the Natural Colour RGB will lose its importance in favour of the True Colour image for surface characteristics and broadcast to the general public; regarding the discrimination of ice/water phase, the Cloud Phase RGB will do a better job.

Climatology of the Maritime Continent is different from the Arabian/North African region, giving rise to changes in RGB appearance.

c) Celil Kaplan, Turkish State Meteorological Service: MSG 0 degree and IODC comparisons over overlap regions – case studies and findings regarding current MSG RGBs.

The Meteosat Indian Ocean Data Coverage service (IODC) allows for better view angle and higher spatial resolution over Turkey and first-time covers Central Asian countries where training efforts are currently focussed. He compared 0° and IODC views for several RGBs and discussed differences.

d) Jochen Kerkmann, EUMETSAT: Comparison of RGBs from GOES-16 ABI, Meteosat-8 SEVIRI, Meteosat-10 SEVIRI and Himawari-8 AHI in overlap areas

He showed overlapping imagery using ePort. There is an imagery resolution improvement for Middle East / Central Asia with IODC. For some applications, coarser resolution and higher viewing angles are more appropriate (e.g., detecting thin dust, thin clouds); generally, though, higher horizontal resolution is preferred. Limb effects are pronounced in the Airmass RGB. With new-generation imagers on the GEO ring, global RGB composites are possible. Overall appearance is similar. Parallax shifts and limb cooling effects need to be considered.

Convection analysis using 3D is better – some European countries still want to see Europe from Meteosat-8 to exploit 3D effects in double-viewing; Europe should have MSG at a longitude further West than 0° because most convective Cb towers are tilted to the East and the larger viewing angle then would favour their analysis. Differences in solar channels can be significant.

Discussion

Strong interest in limb correction factors: it was suggested to collect these for all sensors and publish a table of correction factors, for IR window channels.

The recipe adjustments proposed by JMA should be adopted by NOAA for ABI. This was mainly triggered by the significant impact of the Nighttime Microphysics RGB to detect fog and low clouds.

A standard way of communicating the gamma factor was also called for (2.5 vs 0.4).

6. SESSION 6: PRACTICAL EXAMPLES OF RGBS IN THE FORECASTING AND RESEARCH CONTEXT

a) Yasushi Suzuki, Japan Weather Association (JWA): Use of RGB products for commercial customer

JWA provides commercial weather services to aviation, transport, energy, forecasting, media services (TV etc). It was founded in 1950 and has about 600 employees. RGB products use includes: True colour (for wildfire, daytime, cloud, vegetation applications (autumn leaves)), Natural colour (floating sea ice), Dust (to detect dust and yellow sand, air pollution), Airmass (airmass analysis, jet stream analysis), Night microphysics (fog and low-cloud detection). Himawari-8 RGB and imagery are used in the TV programme.

b) Operational use of RGB products in JMA

Weather forecasting and analysis (R. Nagayama)

Use in daily weather forecasts over Japan, issued on a 20km grid. Marine forecasts include fog warnings (Japan has responsibility for Naval Area XI; SafetyNET responsibility area), and RGB Natural Colour and Day Convective RGB are used here. Day Convective Storm RGB complements weather warnings for remote islands of Japan. Dust and Airmass RGBs are being studied for use in Asian dust advisory and warning services.

VAAC forecasting (H. Tsuchiyama)

He introduced the function of the Tokyo Volcanic Ash Advisory Centre (VAAC). Experiences with using the Dust RGB were presented – advantages are distinguishing ash clouds and meteorological clouds; issues are influence of surface, among others.

Asian dust monitoring (T. Aoyagi)

He presented the effects of Asian dust events on Japan. Dust prediction model results are compared to observations for a May 2017 case. The Dust RGB has been very useful since providing monitoring results day and night.

Sea ice monitoring (Y. Akasaka)

The Sea of Okhotsk is the southernmost sea in the Northern Hemisphere where sea ice is observed every year; the coast of Hokkaido sees sea ice regularly. Sea ice analysis charts are produced based on observations, models. Sea-ice specific analysis are using specialized RGBs (Type A and B).

c) Lee-Ann Simpson, South African Weather Service: Use of RGB products in operational forecasting and training in South Africa

She reported on the training perspective on using RGB imagery – within the context of WMO forecasting competencies and skills. The outcomes of satellite training are assessed practically. There is more demand on SAWS for warning and advisory services, e.g. for sea ice charts for research and rescue cruises to Antarctica. Currently the SUMO software is used for visualization (but will be phased out), McIDAS-V, ePort. ePort pro can overlay imagery, NWP analyses, derived products (RDT, GII). She showed an example for a cell that was not picked up by (insufficient) radar coverage (leading to 90mm rainfall in 30min).

d) Jean-Baptiste Hernandez, Météo-France: RGB in context: Synergie/Synopsis (forecasters workstations)

He showed examples for visualizing satellite imagery using the Météo-France Synopsis and (outdated) Synergie systems, based on a webmapping service. Data can be extracted for areas of interest; this may assist colour-impaired viewers.

e) Humberto Barbosa, Federal University of Alagoas (UFAL), Brazil: MSG RGB and ozone mapping as an index to cyclone intensity in tropical North Atlantic Ocean

He showed an analysis of Hurricane Bill (2009) using Meteosat imagery. Bursts of small particles (ice crystals) were used to identify TC strengthening or weakening (using 3.9µm channel) – this is not common practice by NHS Miami.

f) Renato Galante-Negri, INPE: Practical examples of RGBs in the forecasting context

The production of RGBs was introduced after the 2012 RGB workshop, using Lensky & Rosenfeld paper and WMO/EUMETSAT recipes, however, MSG-based forecasts were not much used in INPE because of lacking coverage of South America. The Dust RGB was adjusted for use with GOES-16 ABI – using the 11.2µm channel instead of 10.4µm. The Snow RGB well represented a snow event in Patagonia (Argentina). The Airmass RGB shows particular features over the Andes in South America. Training material on RGBs for forecasters is being developed. INPE use the SigmaCast tool for visualization.

g) Suman Goyal, IMD: Potential of RGB images of INSAT-3DR satellite in weather forecasting

She introduced the spectral channels of INSAT-3DR, and RGBs Day Microphysics and Night Microphysics. Nowcasting and forecasting of fog in the Ganges valley is very important to India (many disturbances to aviation). She showed examples for dust monitoring from the Arabian peninsula. The geostationary GISAT satellite is planned for launch in 2019, with multispectral and hyperspectral bands.

She suggested compilation of a guidance document on applying RGBs, and requested more training events on RGB applications.

h) Bodo Zeschke, Australian Bureau of Meteorology: Demonstration of short end-to-end forecaster-friendly case studies

He described the structure of a case study which can be consulted by a forecaster within 15 minutes: background, analysis, diagnosis, prognosis. Simulated is call-in of a pilot who wants to land on Melbourne airport – question whether to keep holding, or lift it (due to fog occurrence).

i) Indarto Sugeng, BMKG Indonesia: Case Study from Indonesia

Smoke detection and forest fire prevention are of major importance due to major environmental and economic impact of fires in Indonesia. So far, BMKG used MODIS and VIIRS data. Development of a smoke product based on AHI using several cases is ongoing. Validation of smoke product underway. A local adaptation of the True Colour RGB; 0.4µm is best for detecting smoke.

j) Hyun-Ju Ban, Sejong University: Flood RGB recipte using MODIS and AHI

Previous work used SAR imagery (Sentinel-1) to derive flooding area, however there are limits due to low temporal resolution; explored use of geostationary satellite due to higher temporal resolution. Flooded areas with vegetation cover can be mapped with 3.9µm since warmer during the night (case for Africa). Use of dual Sentinel-1 SAR data can provide daily coverage.

k) Takumi Maruyama, Fog detection product derived from RGB recipes

He used NWP data to distinguish fog and low-cloud areas. The Fog RGB was generated using thresholds during day and night. Cannot detect fog through other clouds.

Discussion

J. Kerkmann remarked that he was very happy to see use of RGB recipes in operations, especially within JMA. Question were raised on how to engage end users, such as forecasters. Credible engagement comes from experienced forecasters who can serve as role models. A special session during user conferences may be an option. L.-A. Simpson asks forecasters annually on use of products, and reasons for non-use.

Training aspects – when new RGBs prove robust during 1-2 years in practice, they qualify for a standard.

7. SESSION 7: COMPILATION OF DEMONSTRATION AND TRAINING MATERIAL (Chair: K. Fuell)

a) Yusuke Ioka, JMA: Himawari training material report of the 8th Asia-Oceania Meteorological Satellite Users Conference

He provided a report on the 2-day training event held with AOMSUC-8 in Vladivostok, Russia, on Himawari-8 imagery using SATAID, which had 115 participants. He showed a good analogy of the RGB principle for finding hot, juicy, meat-stuffed buns.

b) Kevin Fuell, NASA SPoRT: Applications-based training for Multi-spectral Composite Imagery in the GOES-16 Era

Existing training libraries (EUMETView, EUMETRain) often have no specific focus on RGB composites, and often do not include a user feedback component. He introduced the Articulate 360 software plugin to create video, sound, and ppt-based training material. The NASA SPoRT applications library include picture, paragraph and audio/video elements. Fact sheets and quick product guides have been produced. The material has been introduced to the NOAA/NWS.

c) Renato Galante-Negri, INPE: GOES-16 RGB Training Material: some case studies over South America

He showed foundational training modules and on RGBs using GOES-16 (in Portuguese) using the WMO Satellite Skills and Knowledge Guideline. Tests on colour blindness are introduced. Case studies for South America were presented: cold airmass over Amazonia, cyclogenesis, severe events (hailstorm, severe rainfall).

d) Suman Goyal, IMD: Visualization of RGBs through RAPID for Nowcasting over Indian Ocean Region

She introduced the web-based Rapid tool to explore satellite imagery over India; data can be probed for points or areas of interest. A user guide is available.

e) <u>Maria Putsay, Hungarian Meteorological Service RGB training modules, RGB colour interpretation guide and SEVIRI standard RGB quick guides</u>

EUMETRain is a consortium of 6 NMHSs in Europe to organize trainings and generate training material. RGB guides and case studies are included (webcasts, presentations). Quick guides have been produced, and there is substantial interest in these. Their design has to be adapted to the audience (forecasters have little time).

<u>Discussion</u>

Lee-Ann Simpson introduced Regional Focus Groups and Conceptual Models for the Southern Hemisphere:

Regional Focus Groups and block weeks have proven useful to build a user community, e.g. for the Southern Hemisphere. Recordings are very useful material. The interpretation guide for MSG is used as learning material for forecasters and graduate students, in connection with Conceptual Models for the Southern Hemisphere which used RGB composites (Southern Africa – Airmass RGB, South America, Australia). Consideration of more radar interpretation within the Conceptual Models for Brazil and South Africa is missing and needs to be addressed next. South Africa forecasters now produce their own Conceptual Models and perpetuate within the SAWS.

J. Kerkmann suggested creating 1-min short modules based on new satellites in the first 1-2 years, which allow for more cases to be demonstrated to a wide audience. Larger modules (8min) could be produced later, although they allow for more time to include audio and video material.

8. SESSION 8: POTENTIAL STANDARDS FOR OTHER COMPOSITES (Chair: S. Bojinski)

a) <u>Hidehiko Murata, JMA: AHI True Colour Reproduction Imagery</u>

He introduced a colour conversion process based on the CIE XYZ colour system which is required to reproduce the colours seen with human eye. To form the appropriate combination of RGB primary colour bands, a pseudo-green band is calculated for 0.555μm, showing “best” colours for vegetation, soils, and oceans, also in comparison with MODIS imagery. Evaluation technique of obtained XYZ in colour space (chromaticity diagram) to find optimal green band (also for FCI).

Regarding colour blindness, a conversion technique is proposed which could translate colours into a two-dimensional representation of colour (not yet tested).

b) <u>Yuki Takano, JMA: RGB in Broadcast Meteorology, AHI Imagery for Weather Commentary on Clouds</u>

True colour images are sometimes hard to interpret for a general audience, since they may confuse aerosols with clouds or fog. A Green colour RGB is proposed optimized for cloud commentary: land appears green, clouds have more texture, aerosols appear purple, not white (brightness is about half of what it is in True colour RGB).

On relative advantages of the “Green RGB” vs “True Colour RGB” for a forecaster: it is advantageous for a forecaster to use Green colour RGB for explaining weather disturbances, because the imagery suppresses brightness of aerosols and it is easy to focus only on presence and shape of clouds.

On the other hand, True colour RGB is more suitable for monitoring the transport of aerosols than Green colour RGB imagery, because aerosols can be seen more clearly in True colour RGB.

c) Bodo Zeschke, Australian Bureau of Meteorology: Application of the Sandwich Product and variations to this as used in Australia

He illustrated benefits over tropical regions (Singapore case) of the mid-latitude sandwich product; early stages of convective development are better captured by Himawari-8 data (RGB, imagery) than by the radar; later developments will be well captured by radar and lightning imagery. The sandwich product may have weaknesses in operations in cases where days are shorter or when convection occurs at night. Multi-panel display is beneficial to forecasters.

9. SESSION 9: CONCLUDING DISCUSSION (Chair: S. Bojinski)

The main recommendations from the workshop are as follows:

Recommendation 1: Re-name the Dust RGB ’24-hour Microphysics RGB – Dust Version’, and the Ash RGB ’24-hour Microphysics – Ash Version’

Existing RGB composite standards: Recommended Adjustments and Variants

- **Night Microphysics RGB**

	MSG SEVIRI						Himawari-8/9 AHI						MTG FCI
Mid-latitudes	RGB	Ch	λ_c [μm]	Min [K]	Max [K]	γ	RGB	Ch	λ_c [μm]	Min [K]	Max [K]	γ	
	R	CH10-CH09	12.0-10.8	-4	2	1	R	B15-B13	12.4-10.4	-7.5	3.0	1	
	G	CH09-CH04	10.8-3.9	0	10	1	G	B13-B07	10.4-3.9	-2.9	7.0	1	
	B	CH09	10.8	243	293	1	B	B13	10.4	243.7	293.2	1	
Tropics	RGB	Ch	λ_c [μm]	Min [K]	Max [K]	γ							
	R	CH10-CH09	12.0-10.8	-4	2	1							
	G	CH09-CH04	10.8-3.9	0	5	1							
	B	CH05	6.2	273	300	1							

- **Airmass RGB**

Mid-latitudes — MSG SEVIRI

RGB	Ch	λ_c [μm]	Min [K]	Max [K]	γ
R	CH05-CH06	6.2-7.3	-25	0	1
G	CH08-CH09	9.7-10.8	-40	5	1
B	CH05	6.2	208	243	1

Mid-latitudes — Himawari-8/9 AHI

RGB	Ch	λ_c [μm]	Min [K]	Max [K]	γ
R	B08-B10	6.2-7.3	-25.8	0	1
G	B12-B13	9.6-10.4	-41.5	4.3	1
B	B08	6.2	208	242.6	1

Mid-latitudes — MTG FCI: (empty)

Tropics — MSG SEVIRI

RGB	Ch	λ_c [μm]	Min [K]	Max [K]	γ
R	CH05-CH09	6.2-10.8	-25	5	1
G	CH08-CH09	9.7-10.8	-30	25	0.5
B	CH05	6.2	190	243	1

Tropics — Himawari-8/9 AHI: (empty)

Tropics — MTG FCI: (empty)

- **24-hour Microphysics RGB – Dust version**

Mid-latitudes — MSG SEVIRI

RGB	Ch	λ_c [μm]	Min [K]	Max [K]	γ
R	CH10-CH09	12.0-10.8	-4	2	1
G	CH09-CH07	10.8-8.7	0	15	2.5
B	CH09	10.8	261	289	1

Mid-latitudes — Himawari-8/9 AHI

RGB	Ch	λ_c [μm]	Min [K]	Max [K]	γ
R	B15-B13	12.4-10.4	-4	2	1.0
G	B14-B11	11.2-8.6	0	10	2.5
B	B13	10.4	261	289	1

Mid-latitudes — MTG FCI: (empty)

- **24-hour Microphysics RGB – Cloud version**

Mid-latitudes — MSG SEVIRI

RGB	Ch	λ_c [μm]	Min [K]	Max [K]	γ
R	CH10-CH09	12.0-10.8	-4	2	1
G	CH09-CH07	10.8-8.7	0	6	1.2
B	CH09	10.8	248	303	1

Mid-latitudes — Himawari-8/9 AHI

RGB	Ch	λ_c [μm]	Min [K]	Max [K]	γ
R	B15-B13	12.4-10.4	-4	2	1.0
G	B14-B11	11.2-8.6	0	6	1.2
B	B13	10.4	248	303	1

Mid-latitudes — MTG FCI: (empty)

New RGB composite standards

- **Severe Convection RGB**

Region	Satellite	RGB	Ch	λ_c [μm]	Min []	Max []	γ
Mid-latitudes	MSG SEVIRI	R	CH05-CH06	6.2-7.3	-35 K	5 K	1
		G	CH04-CH09	3.9-10.8	-5 K	60 K	0.5
		B	CH03-CH01	1.6-0.6	-75%	25%	1
	Himawari-8/9 AHI						
	MTG FCI						
Tropics	MSG SEVIRI	R	CH05-CH06	6.2-7.3	-35 K	5 K	1
		G	CH04-CH09	3.9-10.8	-5 K	75 K	0.33
		B	CH03-CH01	1.6-0.6	-75%	25%	1
	Himawari-8/9 AHI						
	MTG FCI						

(N.B.: the Severe Convection RGB is being used widely and should be recognized as a standard RGB scheme.)

- **True Colour RGB**

Region	Satellite	RGB	Ch	λ_c [μm]	Min [%]	Max [%]	γ
Mid-latitudes	Himawari-8/9 AHI						
	MTG FCI	R	VIS0.6	0.64	0	100	1
		G	VIS0.5	0.51	0	100	1
		B	VIS0.4	0.44	0	100	1

- **Day Cloud Phase RGB**

Region	Satellite	RGB	Ch	λ_c [μm]	Min [%]	Max [%]	γ
Mid-latitudes	Himawari-8/9 AHI	R	B05	1.6	0	50	1
		G	B06	2.3	0	50	1
		B	B01	0.47	0	100	1
	MTG FCI	R	NIR1.6	1.6	0	50	1
		G	NIR2.3	2.3	0	50	1
		B	VIS0.5 / VIS0.6	0.51 / 0.64	0	100	1

- **Cloud Phase Distinction RGB**

Region	Satellite	RGB	Ch	λ_c [μm]	Min []	Max []	γ
Mid-latitudes	Himawari-8/9 AHI	R	B13	10.4	219.6K	280.7K	1
		G	B03	0.64	0%	85%	1
		B	B05	1.6	1%	50%	1
	MTG FCI						

- **SO2 RGB**

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<tr><th>RGB</th><th>Ch</th><th>λ_c [μm]</th><th>Min [K]</th><th>Max [K]</th><th>γ</th></tr>
<tr><td>R</td><td>B09-B10</td><td>6.9-7.3</td><td>-6</td><td>5</td><td>1</td></tr>
<tr><td>G</td><td>B14-B11</td><td>10.4-8.6</td><td>-5.1</td><td>5.9</td><td>1.2</td></tr>
<tr><td>B</td><td>B13</td><td>10.4</td><td>243</td><td>303</td><td>1</td></tr>
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(N.B.: the thresholds for the Green beam have been updated since the workshop, and realised in SATAID)

- **Fire Temperature RGB**

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<tr><td>Mid-latitudes</td><td></td><td>
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<tr><th>RGB</th><th>Ch</th><th>λ_c [μm]</th><th>Min []</th><th>Max []</th><th>γ</th></tr>
<tr><td>R</td><td>NIR3.9</td><td>3.9</td><td>273 K</td><td>350 K</td><td>1</td></tr>
<tr><td>G</td><td>NIR2.3</td><td>2.3</td><td>0%</td><td>50%</td><td>1</td></tr>
<tr><td>B</td><td>NIR1.6</td><td>1.6</td><td>0%</td><td>50%</td><td>1</td></tr>
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Recommendation 2: Investigate tropical adaptations of the AHI-adjusted and other versions of the Airmass, Night Microphysics, and Convection RGBs (Bodo Zeschke, Jochen Kerkmann and Akihiro Shimizu to investigate).

Recommendation 3: Collect and publish limb correction factors for all sensors for IR window channels.

Recommendation 4: Best practice for communicating the gamma factor in a standard way (2.5 vs 0.4).

Gamma vs 1/gamma – keep current representation of the gamma factor (non-inverted, $V_{out} = V_{in}^{\gamma}$, but note that inverted gamma is used in some contexts / software versions

Decimal precision should generally be to 0.1, and more precise for small ranges

Recommendation 5: Generation and use of training material

A unified quick guide on each of the standard and new RGBs should be produced

Recommendation 6: Best practices for transitioning RGBs into operations

Experience by Bodo Zeschke, Lee-Ann Simpson, Kevin Fuell

Regular surveys

Collect feedback during development (co-development) with forecasters

Credible engagement comes from experienced forecasters who can serve as role models.

A special session during a user conference

Recommendation 7: Best practices for colour-impaired viewers

Allow extracting quantitative data (BTs) for areas of interest; display value when hovering over imagery

JMA approach to converting colours

BOM has initial ideas in this area

Methodologies suggested using current RGBs

In this report, thresholds (max, min) for channel differences are formulated for display in non-inverted mode, i.e., darker pixels indicate low difference values, and bright pixels high difference values. For displaying channel differences in inverted mode, the sign of thresholds or the order of subtraction should be reversed.

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RGB Experts and Developers Workshop 2017
Hosted by JMA, EUMETSAT, and WMO
JMA Headquarters, Tokyo, Japan, 7-9 Nov 2017

Venue: Auditorium, 2nd Floor, JMA HQs

Workshop Objectives:

1. Review of existing RGB composite standards
2. Application of RGBs using new-generation imagers
3. Demonstrating the value of RGBs in context (NWP, products)
4. Compilation of demonstration and training material
5. Exploring new standards for satellite-based composites

DRAFT AGENDA (v20171102)

		Tuesday, 7 November 2017	
8:45		**Registration and obtain ID badge** 8:45-9:15 at JMA HQs Main Entrance	
9:30		**Opening remarks**	*N. Hasegawa, JMA* *S. Bojinski, WMO*
	1.	**Review of existing RGBs**	***Chair: J. Kerkmann***
9:45	a)	Adjusting SEVIRI RGB recipes for AHI	*H. Murata, A. Shimizu, JMA*
10:00	b)	Tropical versions of the Airmass, Night Microphysics and Convection RGBs	*J. Kerkmann, EUMETSAT*
10:15	c)	RGB multichannel color composite images at Meteo France, true-color and pan-sharpening for geostationary and polar orbiting satellites (using 2 to 8 channels, depends on satellite)	*J.-B. Hernandez, MétéoFrance*
10:30	d)	Detection of thin/low aerosol plumes with fine-tuned Dust RGB	*HP Rösli, Switzerland*
10:45	e)	Discussion (15min)	
11:00		Coffee break and group photo (30min)	
	2.	**New RGBs based on newly-available channels in GEO**	***Chair: A. Shimizu***
11:30	a)	New RGBs by using of AHI imagery	*A. Shimizu, Y. Ioka, JMA*
11:45	b)	Discriminating snow and ice clouds	*S. Na, H. Park, KMA*
12:00	c)	Improvement of Dust RGB with AHI	*S. Na, H. Park, KMA*
12:15	d)	Experiences with the Himawari Cloud Phase RGB	*M. Putsay, Hungary*
12:30		Lunch break (1h30min)	
14:00	e)	New Météo-France RGB products usisng HIMAWARI-8 AHI and GOES-16 ABI data	*J.-B. Hernandez, MétéoFrance*
14:15	f)	The dilemma of 4 IR window channels - tuning of the Dust RGB to ABI / AHI	*J. Kerkmann, D. Gencic, EUMETSAT*
14:30	g)	New RGB products from MTG FCI	*J. Kerkmann, EUMETSAT*
14:45	h)	Discussion (30 min)	

	3. RGBs based on LEO imagers, other sensors	***Chair: M. Putsay***
15:15	a) Application of LEO RGBs to Polar and Tropical Regions	*K. McGrath, NASA SpoRT*
15:30	b) Sentinel-3 RGBs and MSG RGBs comparison regarding the spatial resolution needs	*C. Kaplan, Turkey*
15:45	c) Detection of exotic cloud phases with VIIRS RGBs	*HP Rösli, Switzerland*
16:00	d) Discussion (15min)	
16:15	Coffee break (30min)	
	4. Application examples outside MSG 0° footprint	***Chair: B. Zeschke***
16:45	a) AHI RGB products and modification to these as applied over the Australasian/Pacific regions with relevant case studies; the Australian VLab Centre of Excellence Experience	*B. Zeschke, Bureau of Meteorology, Australia*
17:00	b) Transition and Application of SEVIRI-Based RGB Recipes to GOES-16	*K. Fuell, NASA SPoRT*
17:15	c) New features discovered in RGBs outside the MSG (Met-10) footprint (smoke, snow/ice etc.)	*J. Kerkmann, EUMETSAT*
17:30	d) Volcanic eruptions seen in RGB images	*Djordje Gencic, Serbia*
17:45	e) Discussion (30 min)	
18:15	Closing 1st day session	
18:45	**Welcome reception** Tancho-no-ma, 11th Floor, KKR Hotel Tokyo Registration: 18:45-18:55 Opening at 19:00	
20:45	Closing reception	
	Wednesday, 8 November 2017	
	5. Inter comparisons of GEO RGBs in overlap regions	***Chair: J. Kerkmann***
9:00	a) Limb Correction and Adjustments Applied to Imagery Derived from Differing Sensors to Improve Comparison of RGBs	*G. Jedlovec, NASA SPoRT*
9:15	b) Similarities and Differences between MSG and Himawari RGBs	*R. Winkler, Austria*
9:30	c) MSG 0 degree and IODC comparisons over overlap regions - Consisting some case studies and findings regarding current MSG RGBs.	*C. Kaplan, Turkey*
9:45	d) Comparison of RGBs from GOES-16, Met-8, Met-10 and Him-08 in overlap areas]	*J. Kerkmann, EUMETSAT*
10:00	e) Discussion (30min)	
10:30	Coffee break (30min)	

	6. Practical examples of RGBs in the forecasting and research context (together with quantitative products, NWP output, Conceptual models)	***Chair: B. Zeschke***
11:00	a) Use of RGB products for commercial customer	*Yasushi Suzuki, Japan Weather Association*
11:15	b) Operational Use of RGB products in JMA	*JMA experts from operational divisions, JMA*
	○ Operational use of RGB product in weather forecast and analysis	*Ryuji Nagayama*
	○ How VAAC's forecaster uses RGB images?	*Hiroaki Tsuchiyama*
	○ Asian dust monitoring	*Toshinori Aoyagi*
..	○ RGB figures for Sea Ice monitoring	*Yuji Akasaka*
11:45	c) Use of RGB products in operational forecasting and training in South Africa	*L.-A. Simpson, South Africa*
12:00	d) RGB in context: Synergie/Synopsis (forecasters workstations)	*J.-B. Hernandez, MétéoFrance*
12:15	e) MSG RGB and ozone mapping as an index to cyclone intensity in tropical North Atlantic Ocean	*H. Barbosa, Brazil*
12:30	Lunch break (1h15min)	
13:45	**JMA Operation Room Tour** Meet at the auditorium at 13:45	
	Group A / Group B	
14:00	Observation / Seismology/Volcanology	
14:20	Forecast / Observation	
14:40	Seismology/Volcanology / Forecast	
15:00	f) Practical examples of RGBs in the forecasting context	*R. Galante Negri, INPE Brazi*
15:15	g) Potential of RGB images of INSAT-3D/3DR satellite in weather forecasting	*S. Goyal, IMD India*
15:30	h) Demonstration of short End-to-End Forecaster Friendly Case Studies incorporating Himawari-8 data products in combination with other observations and NWP model data; potential for Online Forecast-Simulator type case studies	*B. Zeschke, Bureau of Meteorology, Australia*
15:45	Coffee break (30min)	
16:15	i) Case Study from Indonesia	*S. Indarto, BMKG Indonesia*
16:30	j) Flood RGB recipe using MODIS and AHI	*H.-J. Ban, Sejong University, Korea*
16:45	k) Fog detection product derived from RGB recipes	*T. Maruyama, JMA*
17:00	l) Discussion (30min)	
17:30	Closing 2nd day session	

	Thursday, 9 November 2017	
	7. Compilation of demonstration and training material	***Chair: K. Fuell***
9:00	a) Himawari training report of the 8th Asia-Oceania Meteorological Satellite Users Conference	*Y. Ioka, JMA*
9:15	b) Applications-based Training for Multispectral Composite Imagery in the GOES-16 Era	*K. Fuell, NASA SPoRT*
9:30	c) GOES-16 RGB Training material: some case studies over South America	*R. Galante Negri, INPE Brazil*
9:45	d) Visualisation of RGB through RAPID for Now casting over Indian Ocean Region	*S. Goyal, IMD*
10:00	e) RGB training modules, RGB Colour Interpretation Guide and SEVIRI Standard RGB Quick Guides	*M. Putsay, Hungary*
10:15	f) Discussion (30min)	
10:45	Coffee break (30min)	
	8. Potential standards for other composites	***Chair: S. Bojinski***
11:15	a) AHI True Colour Reproduction imagery	*H. Murata, JMA*
11:30	b) RGB in Broadcast Meteorology, AHI Imagery for Weather Commentary on Clouds	*Y. Takano, Tokyo University*
11:45	c) Application of the Sandwich Product and variations to this as used by Australian Forecasters and as presented during training at the Australian VLab Centre of Excellence	*B. Zeschke, Bureau of Meteorology, Australia*
12:00	d) Discussion (30min)	
12:30	**9. Concluding Discussion**	***Chair: S. Bojinski***
13:00	**10. Closing**	*S. Bojinski, WMO*
	Return ID badge at JMA HQs Main Entrance	

ANNEX II

CHANNEL OVERVIEW OF NEW-GENERATION GEOSTATIONARY IMAGERS

Central Wavelength [µm]	H-8 AHI	GOES-R ABI	FY-4A AGRI	GEO-KOMPSAT-2A AMI	MTG-I1 FCI
0.44 - 0.47	•	•	•	•	•
0.51	•			•	•
0.64 - 0.65	•	•	•	•	•
0.83 - 0.86	•	•	•	•	•
0.91					•
1.4		•	•	•	•
1.6	•	•	•	•	•
2.3	•	•	•		•
3.8 - 3.9	•	•	•	•	•
6.2 – 6.3	•	•	•	•	•
7.0 – 7.1	•	•	•	•	
7.3 - 7.4	•	•		•	•
8.5 - 8.7	•	•	•	•	•
9.6 - 9.7	•	•		•	•
10.3 - 10.7	•	•	•	•	•
11.0 - 11.2	•	•		•	
12.0 - 12.3	•	•	•	•	•
13.3 - 13.5	•	•	•	•	•

STANDARD RGB SCHEMES (2012)

The 2007 RGB Composite Satellite Imagery Workshop[6] recommended several RGB composite imagery schemes, as guidance and best practice. For each table, a derived meteorological / physical parameter is suggested for each of the Red, Blue and Green components, and a suggested scheme to derive these parameters from imager data at different spectral bands is given, using the channel identification definitions given in Table 1 below:

It was agreed to group the RGB products into two 'families', one focussing on atmospheric attributes and the other focussing on surface attributes.

A1) Focus on atmospheric attributes – cloud microphysics (and surface hot spots)

RED	**(LWIR_split_window – LWIR) difference** Cloud optical thickness: thin → thick* Boundary layer moisture: moist → dry	**(LWIR_split_window – LWIR) difference** Cloud optical thickness: thin → thick Cloud water content: low → high	**VIS_long** Cloud optical thickness: thin → thick
GREEN	**(LWIR – MWIR) difference** Cloud phase: water → ice Cloud optical thickness: thin → thick Surface type: rock → sand	**(LWIR – SWIR) difference** Cloud particle size: large → small Cloud phase: ice → water	**NIR / reflected part of SWIR)** Cloud phase: ice → water Hot spots: no → yes
BLUE	**LWIR** Temp. of radiating surface: cold → warm	**LWIR** Temp. of radiating surface: cold → warm	**LWIR** Temp. of radiating surface: cold → warm
Focus of RGB product	**** low cloud, dust, ash-SO_2 (valid 24 hours)**	**hot spots, low cloud/fog (valid night time only)**	**convective intensity (valid day time only)**

* Arrows indicate: from no to full colour (here: thin–black / thick-red)
** Different phenomena (low cloud, dust, ash, SO_2) require different tuning of enhancements (e.g. temperature difference range, gamma contrast enhancement)

The above three RGB schemes assign the same physical meaning to the colour beams. According to the diurnal coverage the red and green beam are assigned to the best proxy available, i.e. equivalent blackbody temperature from IR signals for the 24-hour (including dusk-dawn

[6] WMO (2007): *RGB Composite Satellite Imagery Workshop*, Final Report. Boulder, CO, USA, 5-6 June 2007, http://www.wmo.int/pages/prog/sat/documents/RGB-1_Final-Report.pdf

periods) and night time coverage, solar reflectance for daytime coverage. Goal of these RGBs is to monitor cloud type and structure (including convective intensity in daylight) and the evolution of lifted dust and ash/SO_2 plumes. The first scheme excels in 24-hour coverage including dusk-dawn with only minor colour variations in identifying dust and ash/SO_2 when fine-tuned accordingly. Key to the scheme is the MWIR channel

A2) Focus on atmospheric attributes – air mass, potential vorticity and cloud systems

		Cloudy scene	**Clear scene**
RED	(WV_upper_trop – WV_mid_trop) difference	Cloud top temperature warm → cold*	Height of moisture layer mid-level → high-level
GREEN	(OZONE-LWIR) difference	Cloud top temperature, ozone content above cloud warm → cold, rich → poor	Ozone content rich/polar → poor/subtropical
BLUE	WV_upper_trop inverted	Cloud top temperature, upper tropospheric humidity warm → cold, dry → moist	Upper tropospheric humidity dry → moist
Focus of RGB product		**Cloud top height (colour of low cloud indicating air mass type)**	**Air mass type Potential vorticty anomaly**

* Arrows indicate: from no to full colour (here: warm–black / cold-red)

This RGB scheme highlights the major cloud systems together with polar/subtropical air mass and areas of potential vorticity anomaly. It is an excellent tool for monitoring the synoptic situation. Key to the scheme is the OZONE channel.

B) Focus on surface attributes

RED	**VIS_long**	**NIR**	**VIS_long VIS**	**VIS_long**	**(LWIR-SWIR) difference**	**NIR**
GREEN	**VIS_medium**	**VIS_medium**	**VIS_short SWIR or NIR**	**VIS_medium**	**VIS_long**	**VIS_long**
BLUE	**VIS_short**	**VIS_short**	**SWIR or (SWIR-LWIR) difference LWIR**	**VIS_short**	**VIS_short**	**VIS_short**
Focus of RGB product	**Vegetation**	**Water-Land wetness**	**Snow/ice cover and cloud properties**	**Smoke**	**Fire Hot Spots**	**Pre- and post-fire conditions**

Table 1: Definitions for channel identification used in abovementioned RGB schemes[(1)]

Channel identification[(1)]	MSG SEVIRI	GOES Imager (previous generation)	Himawari Advanced Himawari Imager	GOES Advanced Baseline Imager	MTG Flexible Combined Imager	FY-4A
VIS_broad_band	0.4 – 1.2 µm					
VIS_short			0.45 – 0.49 µm	0.45 – 0.49 µm	0.44 µm	0.47 µm
VIS_medium			0.50 – 0.53 µm		0.51 µm	
VIS_medium	0.56 – 0.71 µm	0.52 – 0.72 µm	0.60 – 0.68 µm	0.59 – 0.69 µm	0.64 µm	0.65 µm
VIS_long	0.74 – 0.88 µm		0.84 – 0.87 µm[(2)]	0.846 – 0.885 µm	0.865 µm	0.825 µm
NIR					0.91 µm	
NIR				1.371 – 1.386 µm	1.38 µm	1.375 µm
NIR	1.50 – 1.78 µm		1.59 – 1.63µm	1.58 – 1.64 µm	1.61 µm	1.61 µm
NIR			2.23 – 2.28 µm	2.225 – 2.275 µm	2.25 µm	2.25 µm
SWIR	3.48 – 4.36 µm	3.78 – 4.03 µm	3.80 – 3.99 µm	3.80 – 4.00 µm	3.80 µm	3.75 µm (2 ch)
WV_upper_trop	5.35 – 7.15 µm	6.47 – 7.02 µm	5.83 – 6.65 µm	5.77 – 6.60 µm	6.30 µm	6.25 µm
WV_mid_trop			6.74 – 7.14 µm	6.75 – 7.15 µm		7.1 µm
WV_mid_trop	6.85 – 7.85 µm		7.25 – 7.44 µm	7.24 – 7.44 µm	7.35 µm	
MWIR	8.30 – 9.10 µm		8.40 – 8.78 µm	8.3 – 8.7 µm	8.70 µm	8.5 µm
OZONE	9.38 – 9.94 µm		9.45 – 9.82 µm	9.42 – 9.8 µm	9.66 µm	
LWIR			10.19 – 10.61 µm	10.1 – 10.6 µm	10.50 µm	10.7 µm
LWIR	9.80 – 11.80 µm	10.2 – 11.2 µm	10.90 – 11.58 µm	10.8 – 11.6 µm		
LWIR_split_window	11.0 – 13.0 µm	11.5 – 12.5 µm	11.90 – 12.87 µm	11.8 – 12.8 µm	12.30 µm	12.0 µm
LWIR	12.4 – 14.4 µm	[(3)] 12.9 – 13.8 µm	13.00 – 13.57 µm	13.0 – 13.6 µm	13.30 µm	13.5 µm

(1) Terminology and attribution to new-generation imager channels needs to be agreed.
(2) B04 is treated as near-infrared band among Himawari users.
(3) Available from GOES-12 onwards