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RGB COMPOSITE SATELLITE IMAGERY WORKSHOP

BOULDER, CO, U.S.A.

5-6 JUNE 2007

FINAL REPORT

First row, right to left: Mr Jeff Wilson, Mr Hans-Peter Roesli (Chairman), Mr Richard Francis

Second row, right to left: Mr Patrick Dills, Dr Andy Kwarteng, Dr Volker Gärtner, Mr Brian Motta

Third row, right to left: Dr Don Hillger, Dr Adamou Garba, Mr Tom Yoksas, Mr Daniel Barrera

1. WELCOME AND WORKING ARRANGEMENTS *(agenda item 1)*

Opening of the workshop

1.1 The workshop was opened and the participants welcomed at 09:30 on 5th June 2007. The Chairman thanked COMET for kindly hosting the event. The workshop noted the unfortunate absence of some invited colleagues, some of whom had declined the invitation due to other commitments and some who had suffered serious travel difficulties that had prevented their attendance.

Adoption of the agenda

1.2 The draft agenda, distributed before the meeting, was agreed without amendment. The agenda is shown as Appendix II.

Working arrangements for the workshop

1.3 The workshop was agreed to be conducted in two sessions on consecutive days involving all participants. It was agreed that the agenda would provide a guiding framework but the proceedings would be focussed around presentations and discussions with the Chairman using as much flexibility as possible to enable the workshop to address the key issues and fulfil its objectives.

1.4 Where presentations and discussions made reference to external information on the routine availability of RGB products or reference works concerned with their generation then such reference would be gathered together in the meeting report. Those that were identified are included in Appendix III.

2. PRESENTATION OF WORKSHOP OBJECTIVES (*agenda item 2*)

Background

2.1 The CBS OPAG-IOS Expert Team on Satellite Utilization and Products (ET-SUP) discussed this topic during its first session in October 2005 and recommended that a workshop to consider standards for RGB composite imagery should be held. This proposal was endorsed by CGMS at its meeting in November 2005. As a first step, the workshop would involve a limited number of experts from satellite operators, product developers, operational services and training centres, with a view to sharing experience and considering commonalities. They would consider recommendations for standards and guidance which would ultimately be presented and discussed in User Conferences and other forums to promote wide acceptance of the workshop's proposals by the user community.

2.2 RGB compositing techniques offer the possibility of compressing multi-spectral information content for optimum visualization, while at the same time preserving pattern and texture of cloud and surface features as well as continuity in the time domain. Thus this technique is of great help for operational users such as forecasters, including specific applications such as the identification of snow cover, the location of stratus/fog conditions, the detection of volcanic ash and many others. Developing a harmonized approach to RGB compositing practices would stimulate the exchange of experience between operational users, sharing of products and tools and would facilitate training efforts.

2.3 The participants were informed of the way in which the workshop fitted into the basic activities of the WMO Space Programme. It was shown to be an important component in the support to product generation for the benefit of global users in response to their requirements.

2.4 The main objectives of the workshop were agreed as follows:

- To assess the need for harmonization of RGB composite imagery products for both operational applications and for training, and to highlight the consequences and benefits of such a harmonization;

- To identify which RGB schemes should be harmonized in priority, considering operational and training requirements;

- To agree on the definition of these RGB schemes on the basis of recognized physical interpretations, to qualify their expected domain of validity and to highlight any potential limitation;

- To review the suitability of present and future multi-spectral imagers spectral characteristics for these RGB schemes and express recommendations regarding future instruments, data dissemination contents and processing systems in order to secure the capability of generating these harmonized RGB products in the future.

3. PRESENTATION ON SEVIRI RGB COMPOSITE SATELLITE IMAGERY FOR OPERATIONAL FORECASTING AND TRAINING *(agenda item 3)*

3.1 The Chairman presented the well-established EUMETSAT approach to the definition of RGB products based on SEVIRI imagery data. The presentation concentrated on the so-called ‘cloud microphysical’ RGB schemes along with an air mass product with particular emphasis being placed on the physical interpretation of the spectral channels, or combination of channels, used.

3.2 Each RGB scheme comes with a colour key that identifies the colours shades of different cloud types and surface features.

3.3 By assigning the same physical meaning to the colour beams of the 'cloud microphysical' RGB schemes and by selecting the best available channels or channel differences as proxies, the resulting colour keys remain quite consistent.

3.4 The 'microphysical' RGBs highlight types and properties of clouds including dust, ash and SO_2 plumes as well as convective activity in daytime. The air mass product combines the identification of major cloud systems with the depiction of air mass types and tropopause breaks pointing to anomalies in potential vorticity field.

3.5 The presented material highlighted slight differences between Meteosat-8 and Meteosat-9 products. This is due to small temperature ranges (order of 6K) being expanded to the full intensity range of a colour beam on one hand and, on the other hand, to small differences of in the radiometers, their calibration and their orbital positions. The impact on the resulting colour keys negligible however, and does not impact on their use in operations.

3.6 The question of using RGB products in combination with data from other sources was raised, especially within GIS applications. It was noted that there may be a need to modify the RGB product approach to maximise the effectiveness of their combination with other data. Examples include reprojection, the use of ‘thresholding techniques’ to reveal only those regions of interest (depending on the context of the application).

3.7 It was commented that judicious use of a colour key, displayed along side the products, perhaps focussing on only those areas (colours) of significance may add value to the product and may ease the problem of assimilating the information content as well as minimising the risk of misinterpretation.

3.8 Using the air mass RGB product as an example, it was commented that RGB products (and indeed satellite products in general) have great potential to contribute to the verification of NWP model data output – and consequently on model forecast confidence – and that the issues of displaying products merged with model output fields was of particular relevance here.

3.9 The question of "tuning" the product generation process (i.e. selecting value ranges for the Red, Green and Blue intensities and applying a contrast enhancement factor) was felt by the group to be something that should not be prescribed but should be guided by the context of the situation – for example, geographical region, synoptic conditions, season, etc.

3.10 It was noted that we should be progressing from focussing on what is possible in a theoretical context towards defining what is most useful, especially for operational forecasting purposes.

4. OTHER PARTICIPANTS PRESENTATIONS *(agenda item 4)*

CIRA

4.1 CIRA presented some current developments using GOES imager data (for example a three-color albedo product) as well as developments preparing for the exploitation of the Advanced Baseline Imager (ABI) instrument data of GOES-R. These latter products are being generated using simulated data obtained from MODIS and include fog and dust RGB products based on the same approach as adopted by EUMETSAT.

4.2 It was noted that the product usefulness benefits from the application of solar zenith angle corrections.

4.3 Two variants of the "natural" colour RGB products were shown, the first similar to the SEVIRI (1.6μm, 0.8μm, 0.6μm) product and the second using (0.6μm, 1.6μm, 3.9μm) – with only the reflected (solar) part of the 3.9μm used – which seemed to give better discrimination of snow-covered surfaces.

4.4 In addition to the 'classic' method of allocating combinations brightness temperatures or reflectances to the Red, Green and Blue inputs it was shown that there was potential value in first performing Principle Component Analysis on the multi-spectral data and then assigning the PCI components (eigenvalues) to RGB.

UK Met Office

4.4 The WMO representative, who was, until recently, working in the UK Met Office, reported some experiences from the introduction of RGB products, generated from SEVIRI data, to operational forecasters at the UK Met Office. The workshop noted the real obstacles that had to be overcome before the products could be effectively used in the time-critical forecasting environment of an operational agency. In particular it was recognised that forecasters have a huge amount of information available to them, which means:

- They have to be very selective in what they choose to use;
- They cannot spend very long trying to extract the 'signal from the 'noise';
- They need to be able to access the right products for the current situation and extract what they need from those products quickly and effectively.

4.5 This has tended to make RGB products less popular than they might otherwise be. Some ways to address these problems had been tried, including:

- The renaming of the products to be associated to a meteorological 'theme' (e.g. "snow", "fog", "severe convection", "cloud phase", etc) and grouping them with other products on the same theme;
- Adding coasts, grids, towns, etc to aid navigation and hence improve usefulness;
- Improving their timeliness of product generation and delivery;
- Making all RGB products available as movie loops;
- Focussing only on the significant 'signals', for example, by removing colour from the rest;
- Maintaining a "showcase" of products under development and new variants of existing products and, by actively seeking feedback and suggestions, deciding on those products which have the potential to be widely used.

NRL

4.6 The work of NRL, Monterey was briefly discussed via a guided tour of the NexSat web pages. The NexSat project is focussing on planning product derivation from NPOESS data. They include products based on GOES and MODIS data using colour in a variety of ways, including RGB techniques. Many of these products are operationally used by the US Navy.

COMET

4.7 COMET demonstrated a MetEd training module which illustrated the use of RGB products from MODIS to detect areas of blowing snow.

5. PRELIMINARY DISCUSSION – AGREEMENT OF STRUCTURE & OBJECTIVES OF GENERAL DISCUSSION *(agenda item 5)*

5.1 The group agreed that the scope of the general discussions should be limited to products that make use of 'coupled' elements from multi-spectral data rather than embracing all the uses of colour to enhance satellite imagery.

5.2 The group took note of the problems associated with RGB imagery interpretation by those who suffer from degrees of colour-blindness. This was recognised as a very real problem but one for which the group were not equipped to address.

5.3 Despite the workshop focus being firmly on RGB products and their derivation from multi-channel imager data, the group felt it worth noting that the use of RGB products would always be complementary to – rather than a replacement of – the traditional and widely practiced methods of viewing 'basic' single-channel greyscale imagery products that have, for many years, been the standard way of displaying imagery data from 3-channel radiometers (IR, VIS, WV).

5.4 The workshop acknowledged the benefits that would stem from a harmonization of RGB product definition. They recognised that guiding principles would be extremely valuable but that a full (prescriptive) harmonization of product definition schemes was probably impractical. The group felt that such guidance should be generic enough to be applicable to the wide range of current and future imaging instruments (with their different spectral characteristics) but also specific enough to ensure widespread commonality of approach.

6. GENERAL DISCUSSION *(agenda item 6)*

6.1 The group felt it worthwhile to recall, and take heed of, the well-established and commonly used schemes in place for processing AVHRR and MODIS data into RGB products since these serve as the heritage to the current RGB product development.

AVHRR

RED	CH01 (0.6 μm)	CH01 (0.6 μm)	CH03B (3.7 μm)
GREEN	CH02 (0.8 μm)	CH03A (1.6 μm)	CH04 (10.8 μm)
BLUE	CH04 (3.7 μm)	CH04 (10.8 μm)	CH05 (12.0 μm)

MODIS

RED	CH01 (0.6 μm)	CH01 (0.6 μm)	CH01 (0.6 μm)	CH26 (1.3 μm)
GREEN	CH04 (0.5 μm)	CH02 (0.8 μm)	CH06 (1.6 μm)	CH06 (1.6 μm)
BLUE	CH03 (0.4 μm)	CH03 (0.4 μm)	CH31 (11.0 μm)	CH31 (11.0 μm)

6.2 The group recalled the spectral channels of the currently flying multi-spectral radiometers (i.e. those with more than the 'first generation standard' set of IR, WV and VIS) and also the Advanced Baseline Imager for next generation GOES (since RGB products are already under development based on simulated data). The group concluded that there is an issue regarding the terminology used to identify spectral channels used for RGB product development. Examples exist in which the channels used are described in terms of nominal centre frequency, wave number, channel number (different for different instruments) and also channel identification (e.g. "LWIR" = long wave infra-red). It was decided that this issue would also benefit from harmonization and the following definitions were formulated.

Channel identification	**Meteosat**	**GOES (current generation)**	**MTSAT**	**GOES (next generation)**
VIS_broad_band	0.4 – 1.2 μm			
VIS_short				0.45 – 0.49 μm
VIS_medium	0.56 – 0.71 μm	0.52 – 0.72 μm	0.55 – 0.9 μm	0.59 – 0.69 μm
VIS_long	0.74 – 0.88 μm			0.846 – 0.885 μm
NIR				1.371 – 1.386 μm
NIR	1.50 – 1.78 μm			1.58 – 1.64 μm
NIR				2.225 – 2.275 μm
SWIR	3.48 – 4.36 μm	3.78 – 4.03 μm	3.5 – 4.0 μm	3.80 – 4.00 μm
WV_upper_trop	5.35 – 7.15 μm	6.47 – 7.02 μm	6.5 – 7.0 μm	5.77 – 6.60 μm
WV_mid_trop				6.75 – 7.15 μm
WV_mid_trop	6.85 – 7.85 μm			7.24 – 7.44 μm
MWIR	8.30 – 9.10 μm			8.3 – 8.7 μm
OZONE	9.38 – 9.94 μm			9.42 – 9.8 μm
LWIR				10.1 – 10.6 μm
LWIR	9.80 – 11.80 μm	10.2 – 11.2 μm	1.03 – 11.3 μm	10.8 – 11.6 μm
LWIR_split_window	11.0 – 13.0 μm	11.5 – 12.5 μm	11.5 – 12.5 μm	11.8 – 12.8 μm
LWIR	12.4 – 14.4 μm	(1) 12.9 – 13.8 μm		13.0 – 13.6 μm

(1) GOES-12 only

7. WORKSHOP RECOMMENDATIONS *(agenda item 7)*

7.1 The workshop concluded that guidance could be captured in a table of generic approaches to the various RGB products. For each table of guidance 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 from the table above.

7.2 It was agreed to group the RGB products into two 'families', one focussing on atmospheric attributes, for which EUMETSAT took the lead in discussion of guidance, and the other focussing on surface attributes, for which the COMET/UCAR/CIRA experiences would provide the inspiration.

7.3 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 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

7.4 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.

7.5 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**

7.4 The workshop noted that the tables also implicitly infer recommendations on the channels to be preserved or implemented on future imaging radiometers. MWIR, WV, NIR and VIS-short channels, up to now rarely implemented, appear to be the favoured candidates for a wider implementation in particular in geostationary orbit.

8. CLOSURE OF THE WORKSHOP *(agenda item 8)*

The workshop was closed at 15:30 on 6th June.

APPENDIX I

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APPENDIX II

AGENDA

1. WELCOME AND WORKING ARRANGEMENTS
    1.1 Opening of the workshop
    1.2 Adoption of the agenda
    1.3 Working arrangements for the workshop

2. PRESENTATION OF WORKSHOP OBJECTIVES

3. PRESENTATION ON SEVIRI RGB COMPOSITE SATELLITE IMAGERY FOR OPERATIONAL FORECASTING AND TRAINING

4. PARTICIPANTS PRESENTATIONS

5. PRELIMINARY DISCUSSION – AGREEMENT OF STRUCTURE & OBJECTIVES OF GENERAL DISCUSSION

6. GENERAL DISCUSSION

7. WORKSHOP RECOMMENDATIONS

8. CLOSURE OF THE WORKSHOP

APPENDIX III

LINKS AND REFERENCES

EUMETSAT MSG Interpretation Guide
http://oiswww.eumetsat.org/WEBOPS/msg_interpretation/index.html

EUMETSAT Derived Product Imagery
http://www.eumetsat.int/Home/Main/Image_Gallery/Derived_Product_Imagery/index.htm?l=en

EUMETSAT Product Generation Description
http://oiswww.eumetsat.org/SDDI/html/product_description.html

EUMETSAT Best Practices for RGB compositing of multi-spectral imagery
http://oiswww.eumetsat.org/SDDI/html/doc/best_practices.pdf

CIRA/RAMM Three-color Area File Generation
http://rammb.cira.colostate.edu/quarterly_reports/1qtr06/1stQuarter/MRProductDevelopment.htm

NOAA SSD Products and Services (includes routinely generated RGB products from GOES data)
http://www.ssd.noaa.gov/PS/index.html

NOAA/RAMMB GOES ABI (simulated) three-color albedo product (poster)
http://npoesslib.ipo.noaa.gov/IPOarchive/ED/Outreach_Materials/public_presentations/AMS/2007/Posters/S1-P18-117094-Final-Hilger-DeMaria.pdf

CIRA GOES ABI (simulated) three-color products (AMS paper)
http://ams.confex.com/ams/pdfpapers/99728.pdf

NASA/GSFC MODIS Rapid Response System (includes near real-time MODIS RGB products)
http://rapidfire.sci.gsfc.nasa.gov/realtime/

CIRA/RAMMB AVHRR RGB products for identifying cloud over snow
http://rammb.cira.colostate.edu/wmovl/VRL/Tutorials/nrlsat/print/p_cos.htm

NRL NexSat NPOESS Next Generation Weather Satellite Demonstration Project
http://www.nrlmry.navy.mil/NEXSAT.html

MetEd training module using RGB techniques to identify blowing snow (requires registration)
https://www.meted.ucar.edu/loginForm.php?urlPath=norlat/snow/blowingsnow_case