Introduction to Image processing & RGB composites

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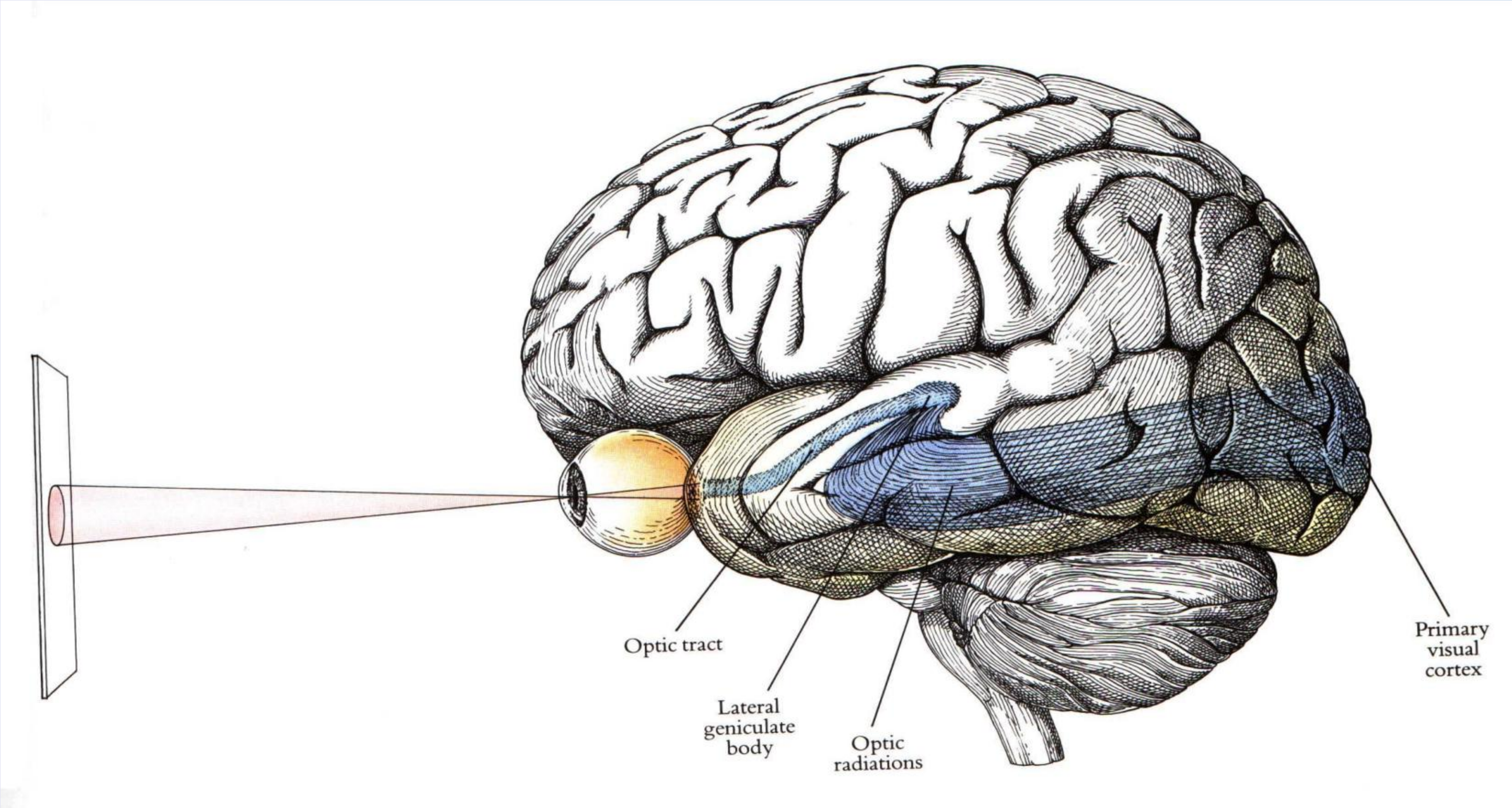
Human Natural Remote Sensing Device

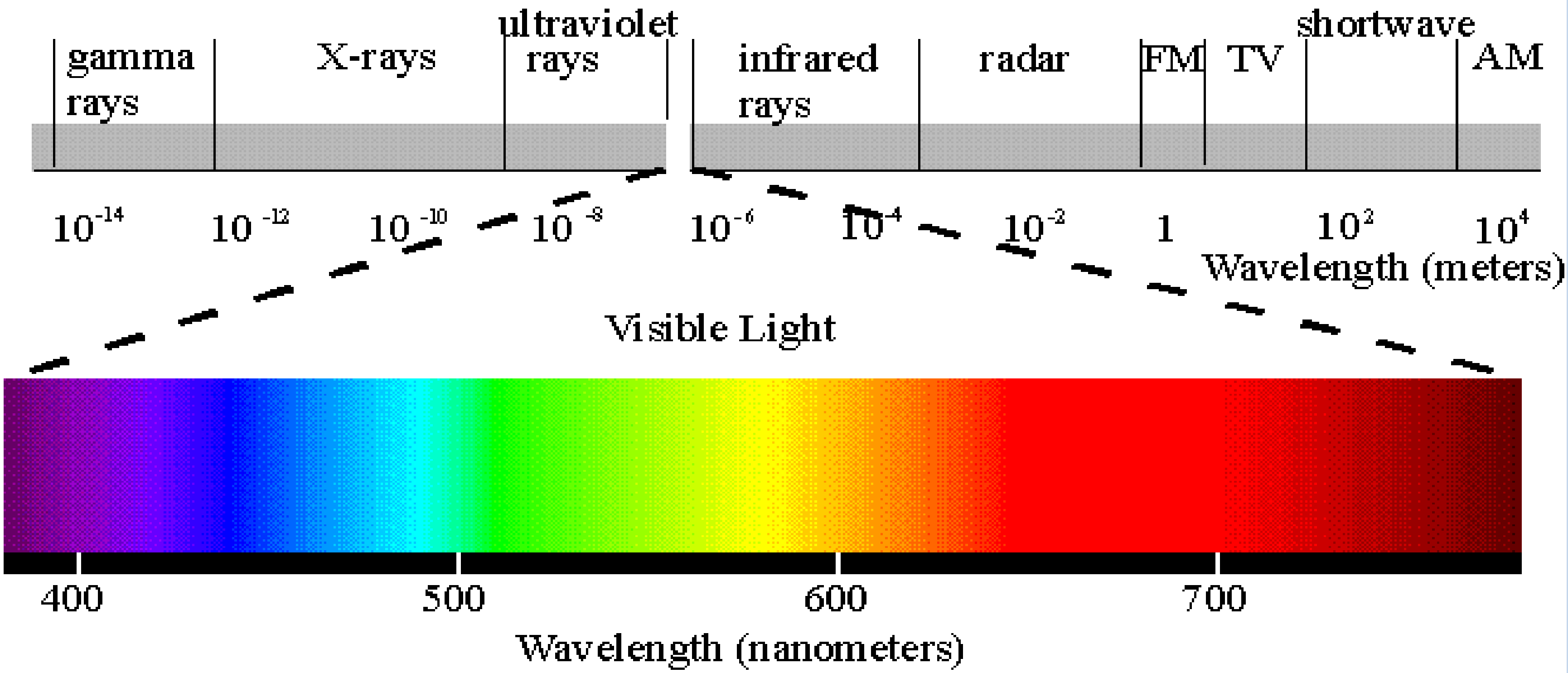
In the beginning…

we'll have a look at the human eye

Our Vision

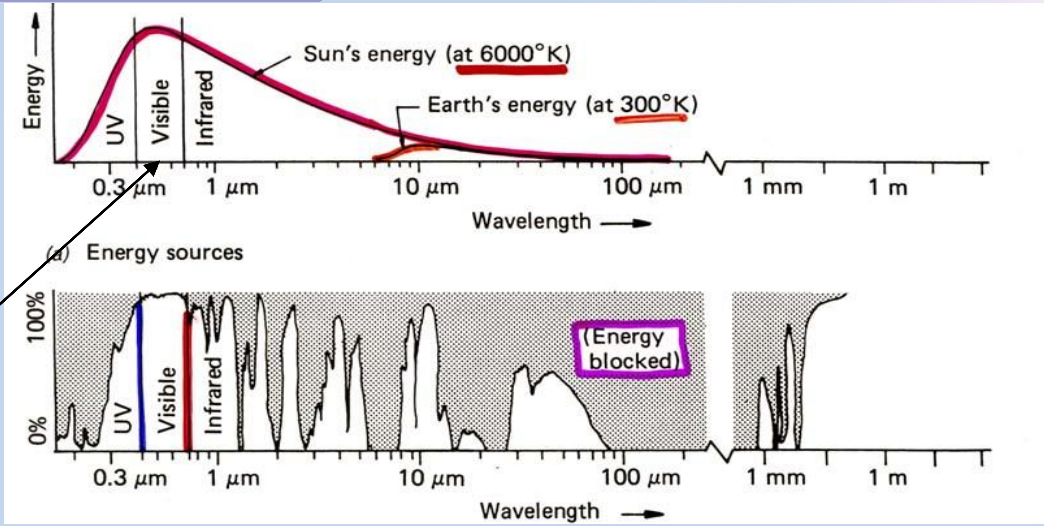

Optic tract
Lateral geniculate body
Optic radiations
Primary visual cortex

Vision and the "Electromagnetic Spectrum"

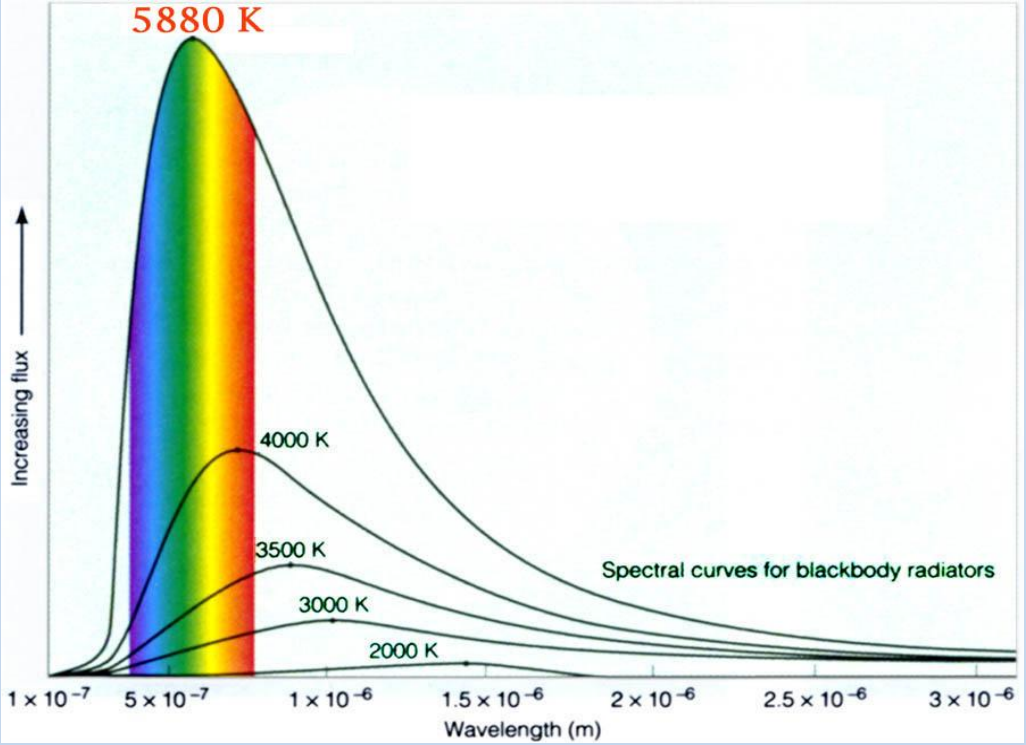


The electromagnetic spectrum
from "The Joy of Visual Perception: A Web Book"
http://www.yorku.ca/eye/

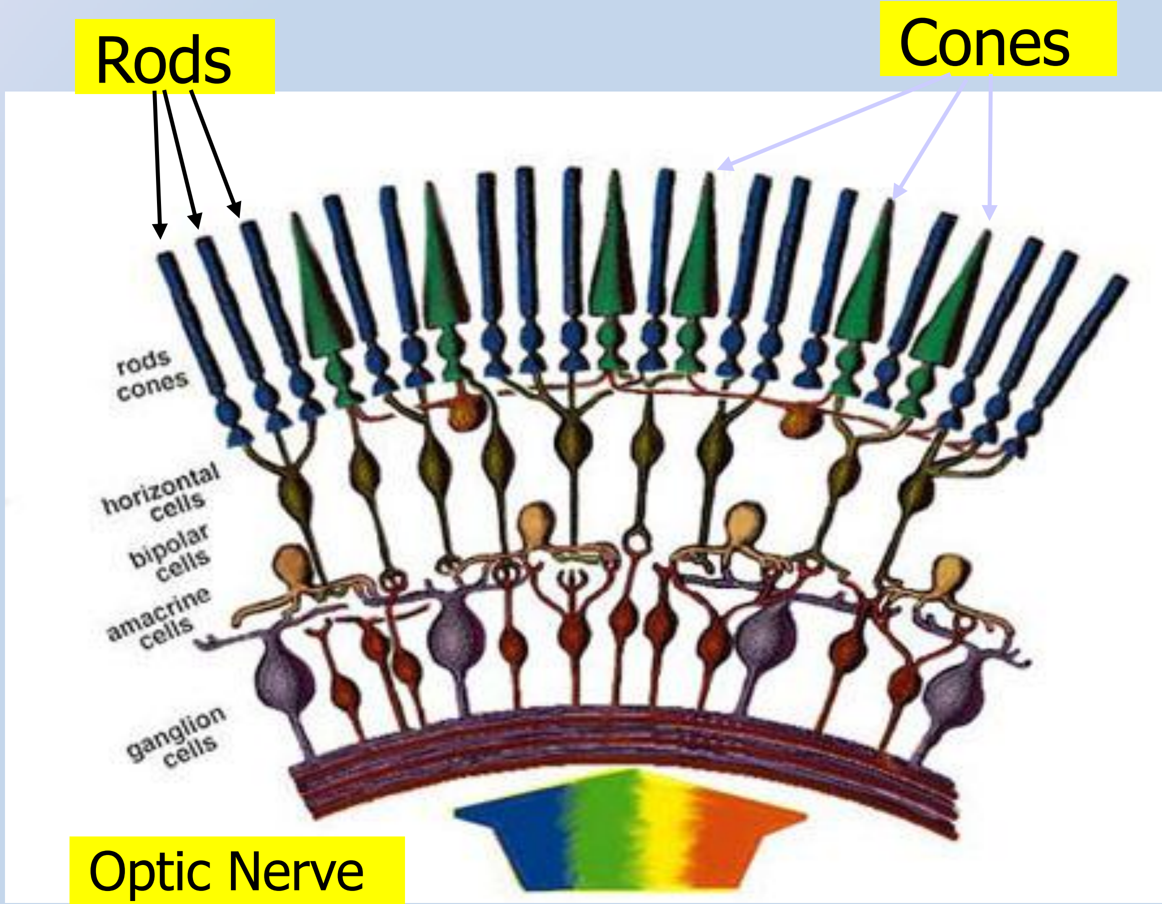
Human Natural Remote Sensing Device



Our vision is optimized for receiving the <u>most abundant spectral radiance</u> our star emits.

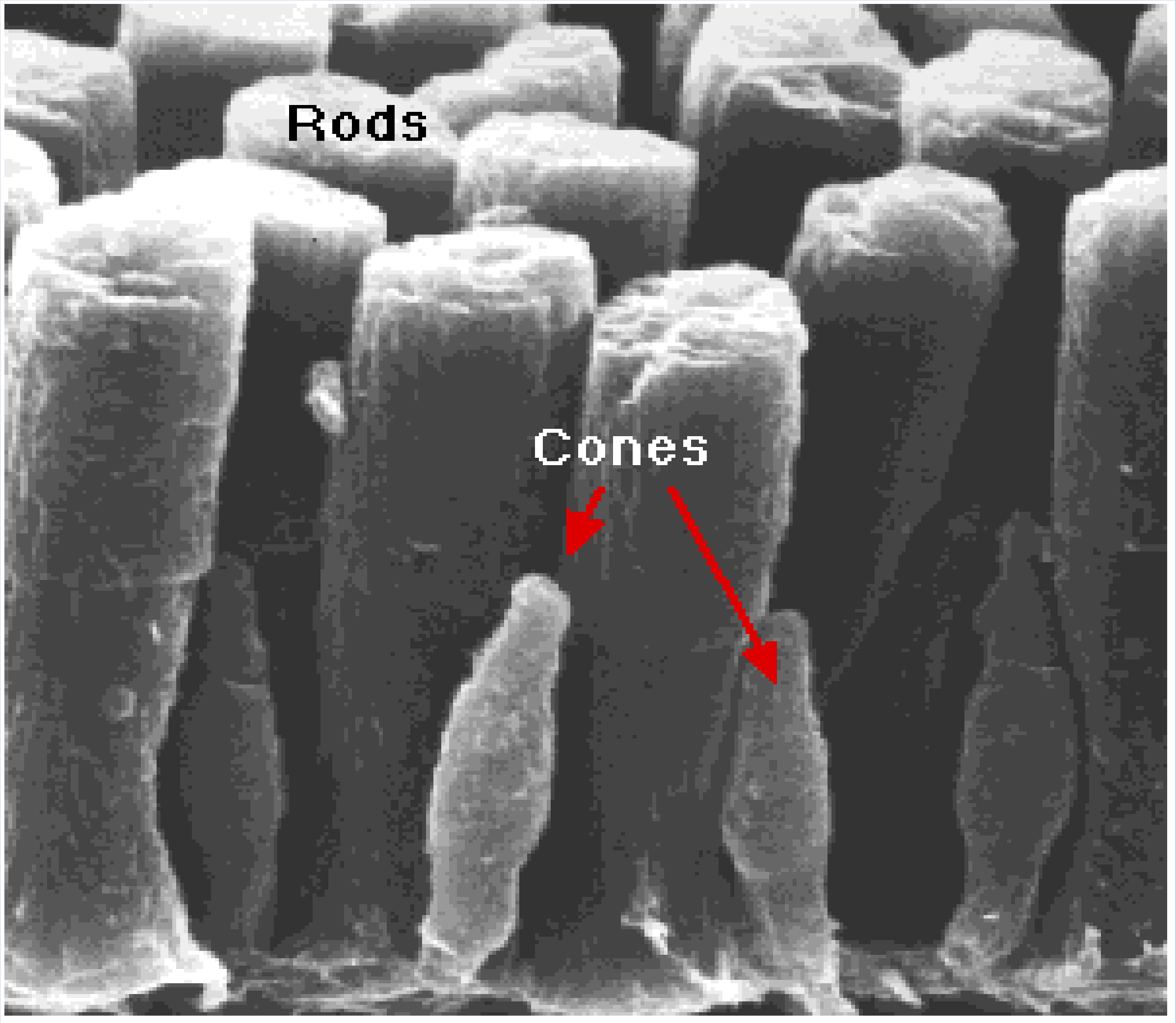


Photoreceptors: Rods and Cones



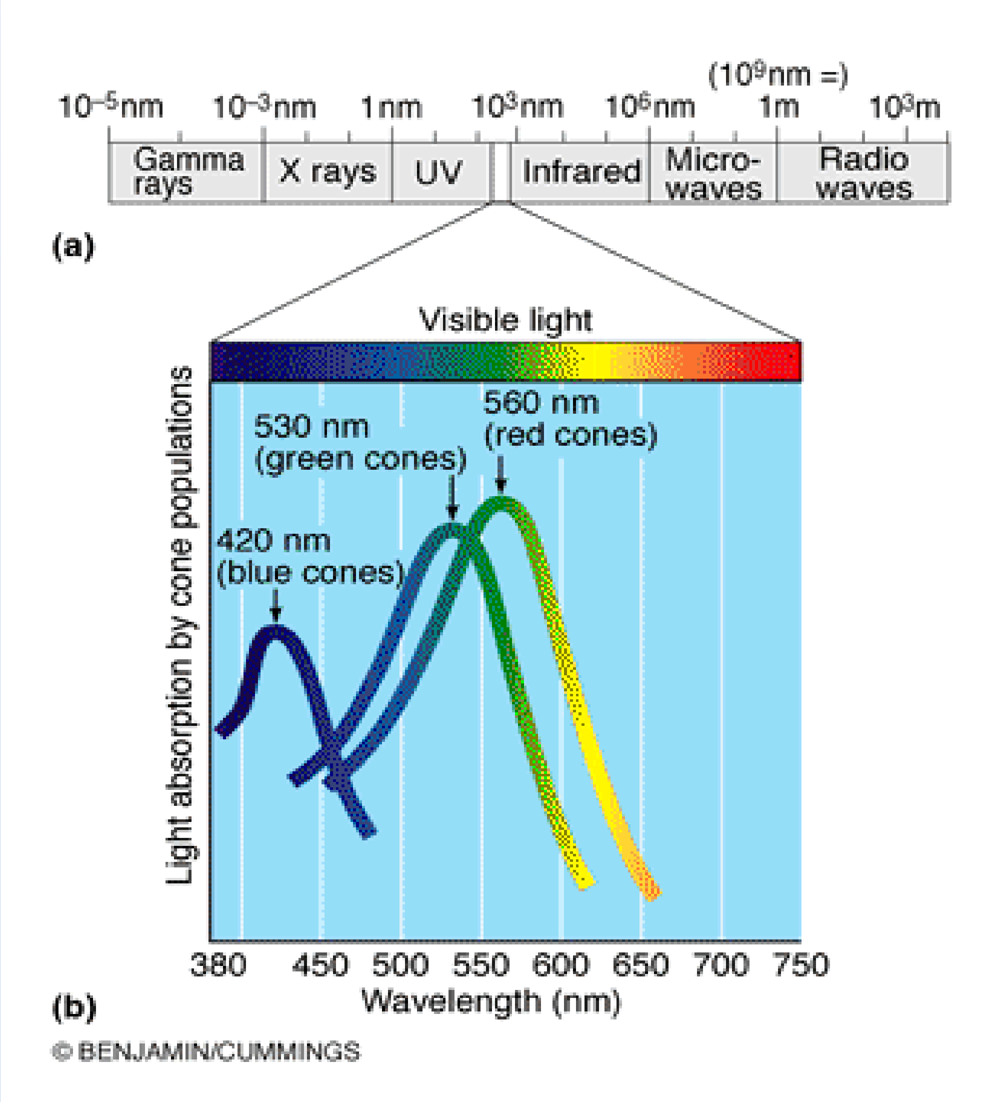
Retina schematic

Human Natural Remote Sensing Device



Human Natural Remote Sensing Device

Three Cone Types



Human Natural Remote Sensing Device

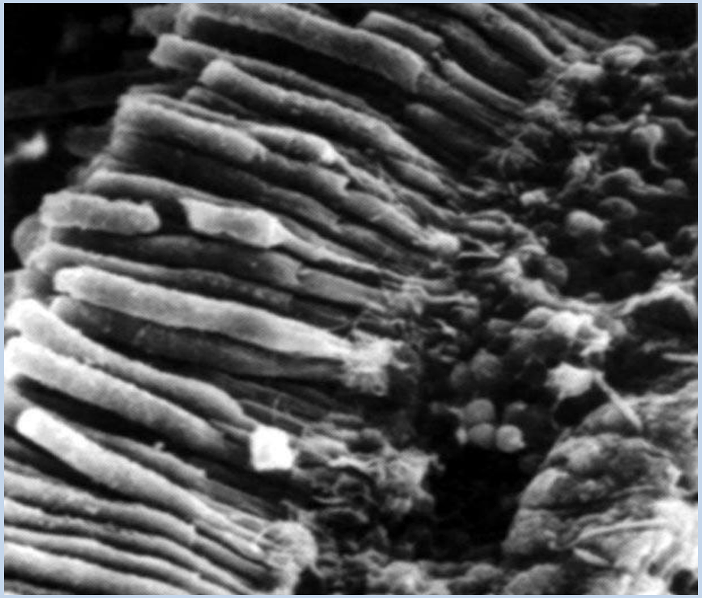
Human

Eye

120 Million rods, 5 Million cones

Cones--color sensitive, form sharp images, require many photons

Rods are more, but not color sensitive, & form blurred images



Retina Rods & Cones: our visible detectors

Human Natural Remote Sensing Device

Is This What Dichromatic Vision Looks Like?

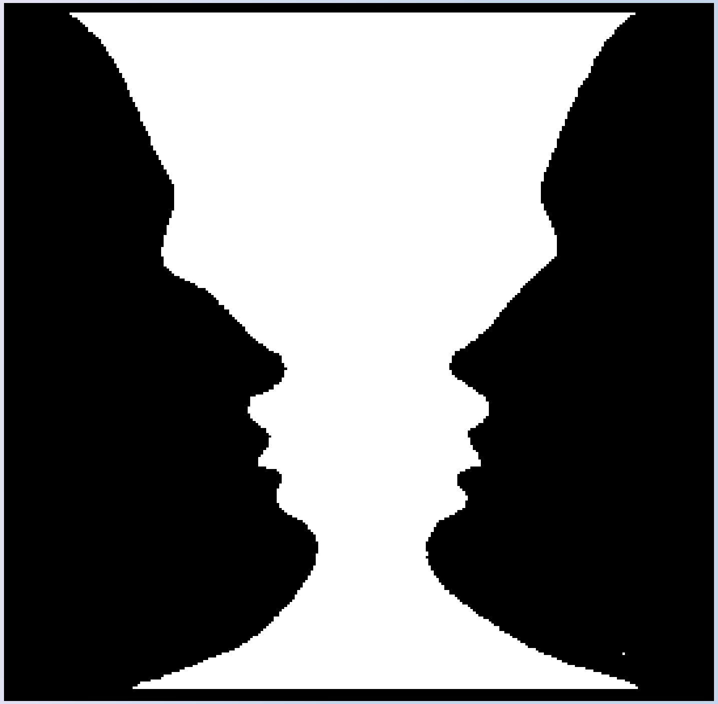
Many animals are dichromats

What would a tetrachromat see?

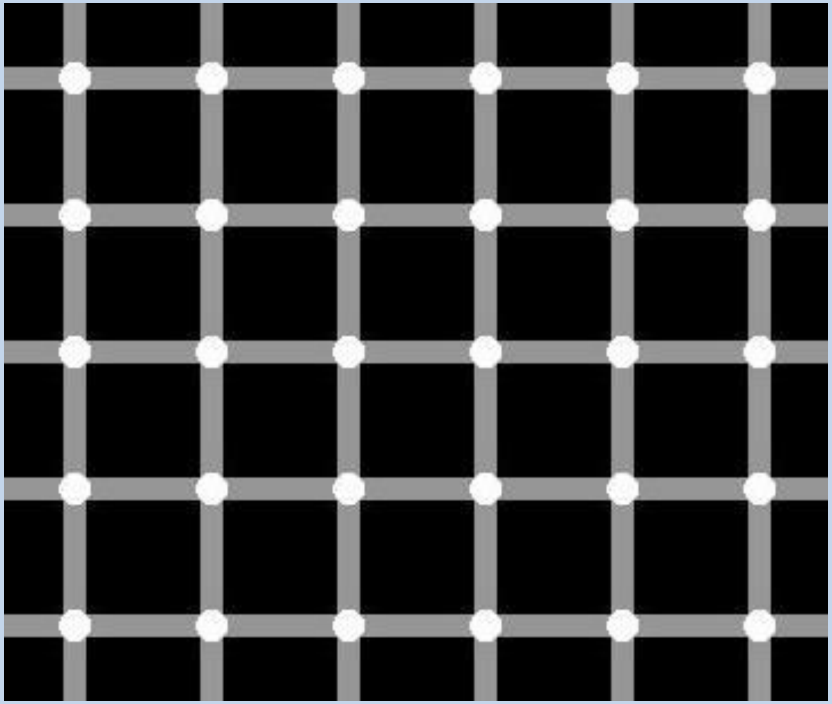
Birds--more cones, “faster” eye muscles, more support, and **best vision (8x better than ours)**

Nocturnal animals have big eyes & more rods/fewer cones

Subjective observation
Illusions

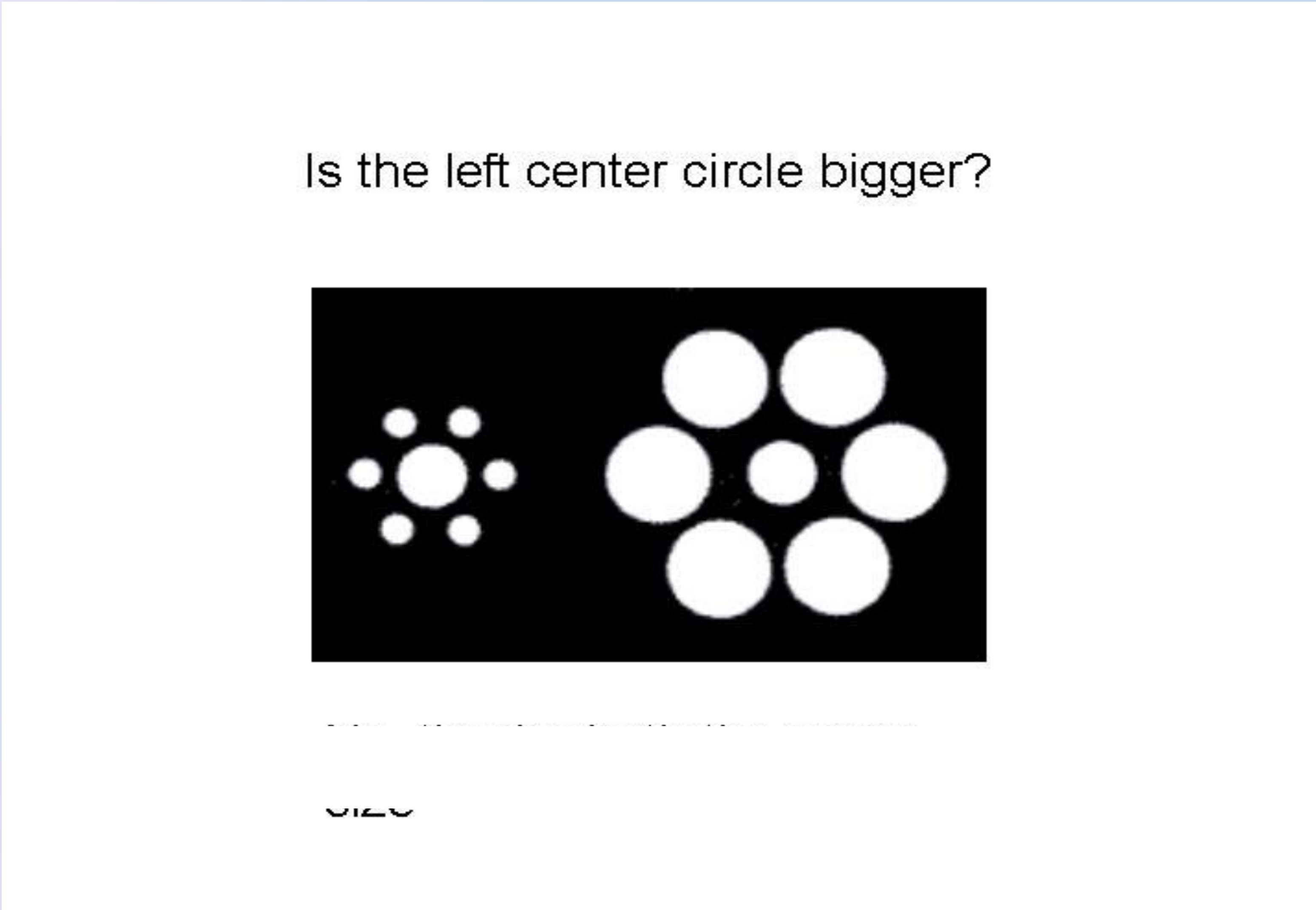


A vase or two faces?

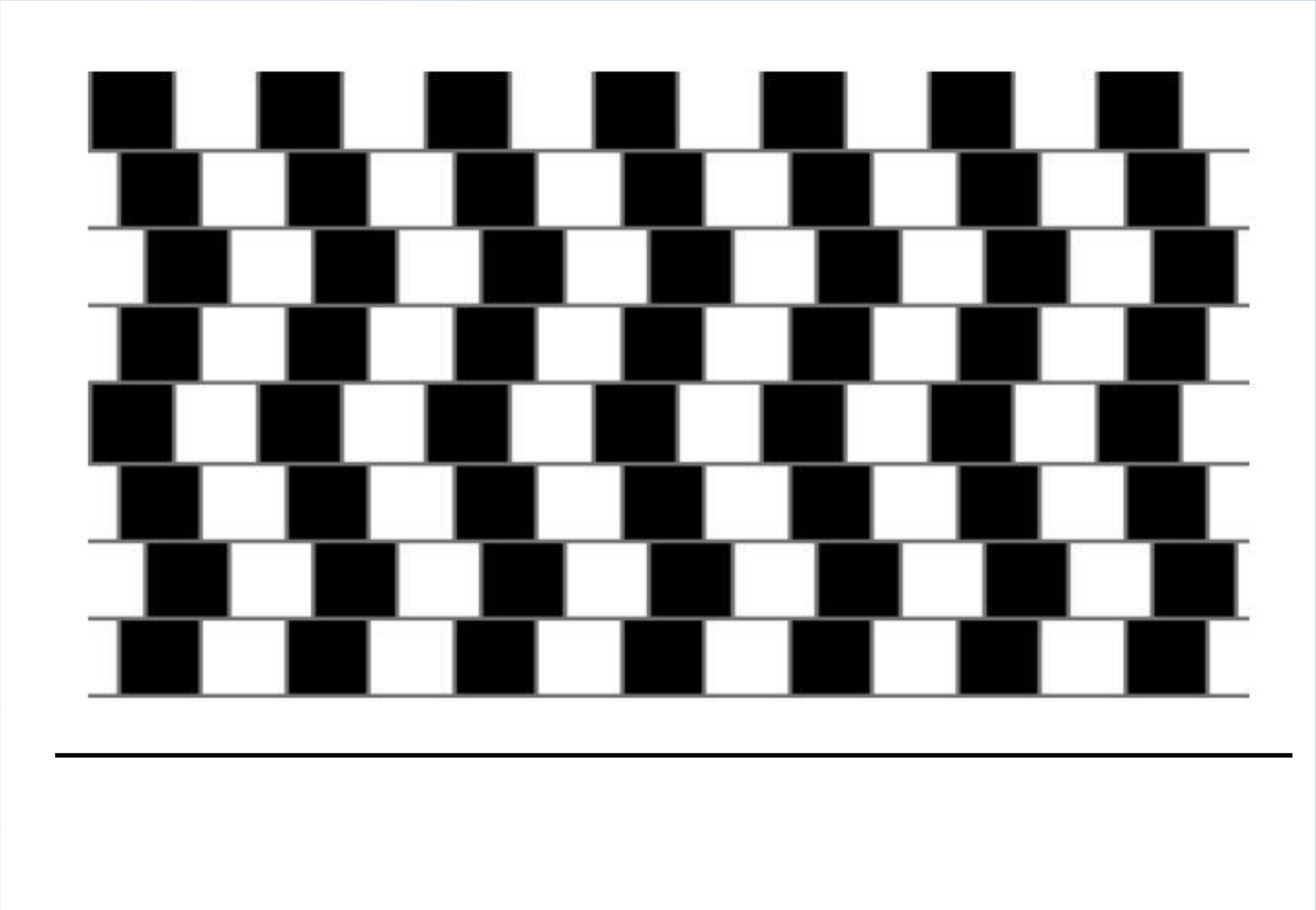


Count the black spot

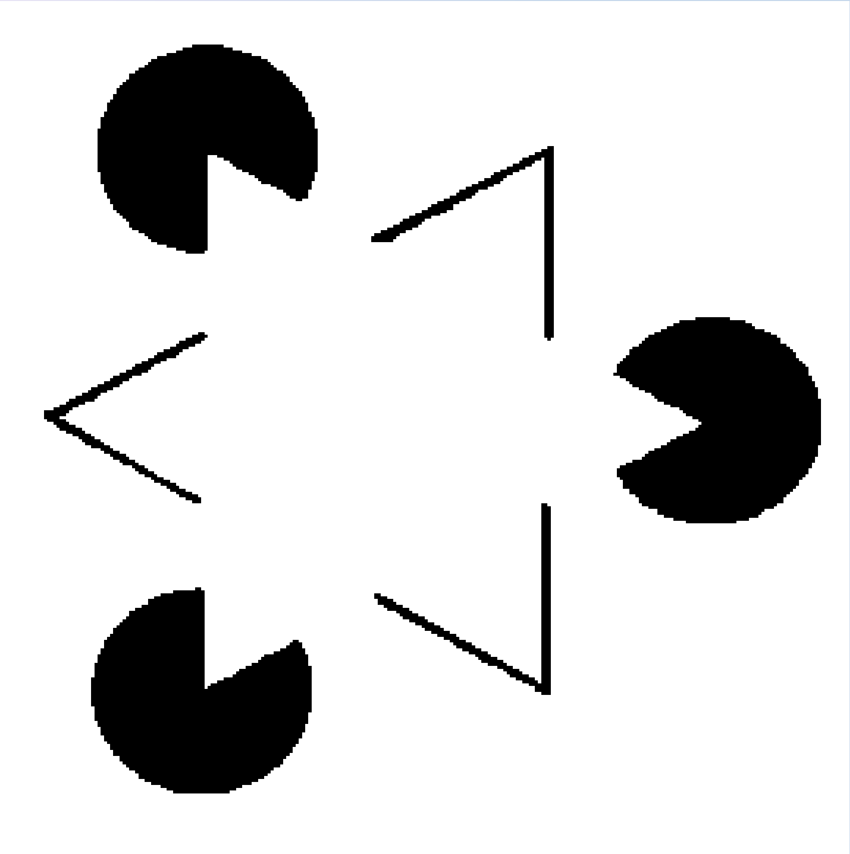
Human Natural Remote Sensing Device

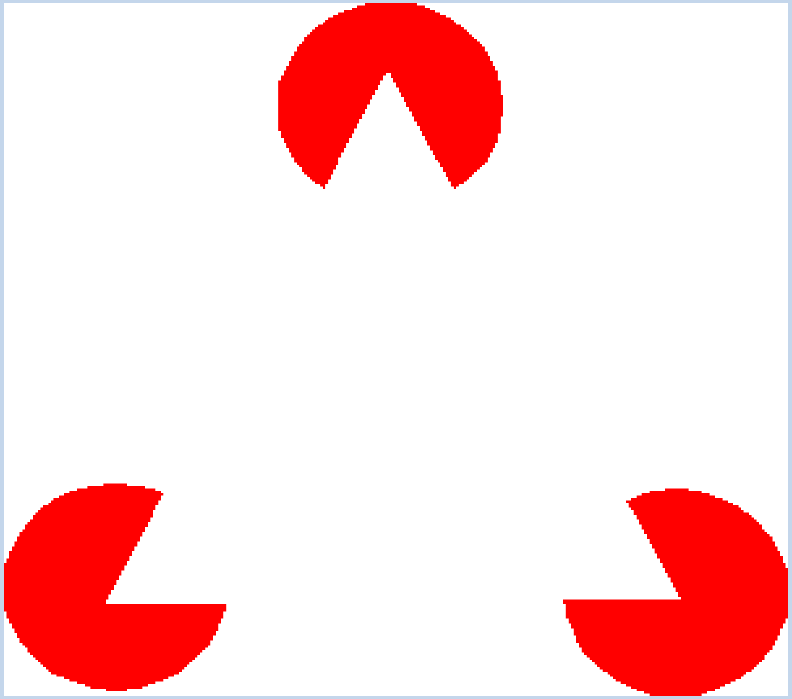


Are the Horizontal Lines Straight?



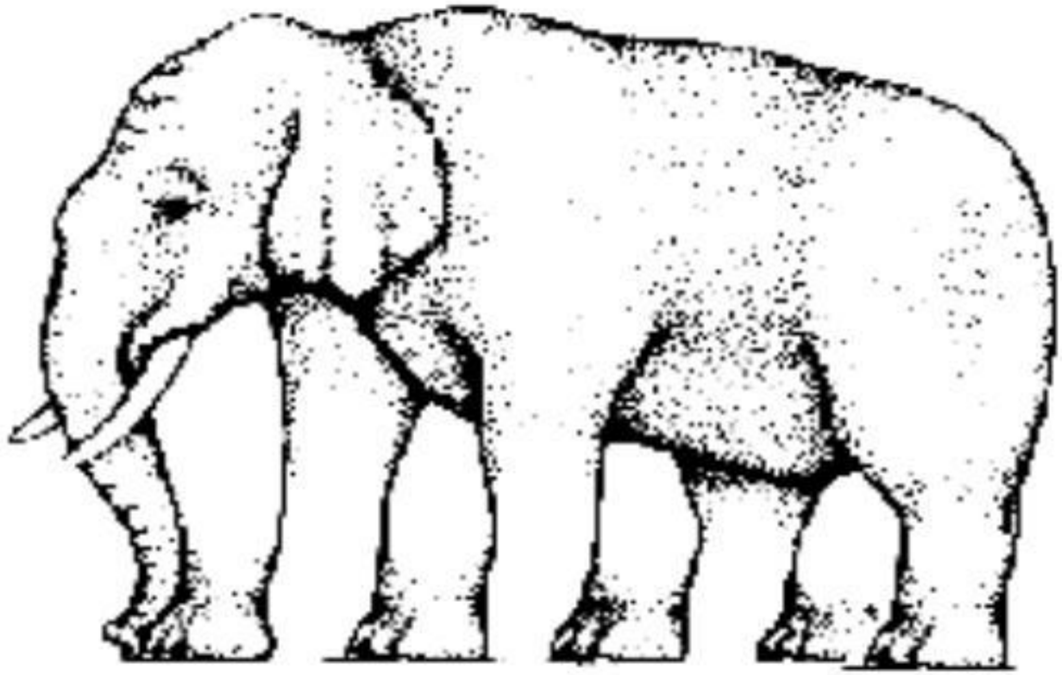
Do You See the White Triangles?





Human Natural Remote Sensing Device

How Many Legs Does the Elephant Have?

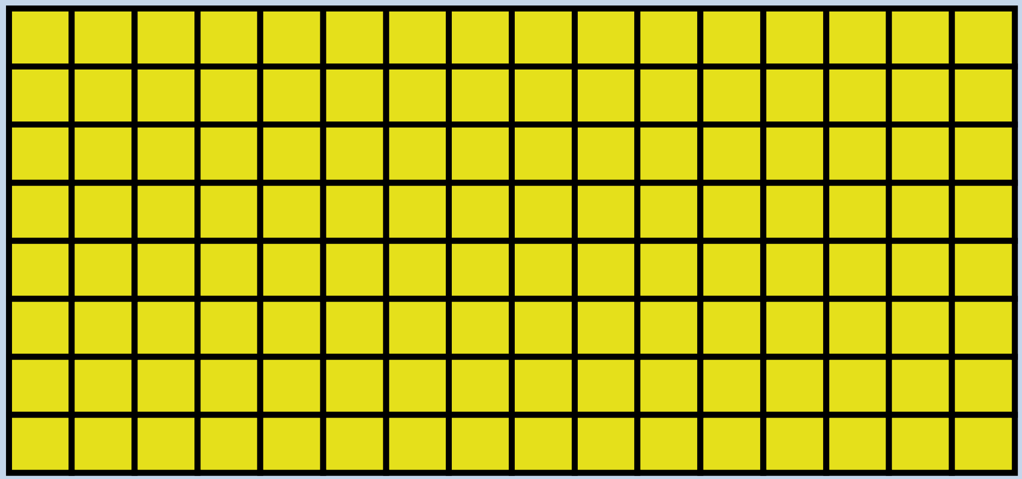


Basic digital images concepts

Digital images

What is a digital image ?

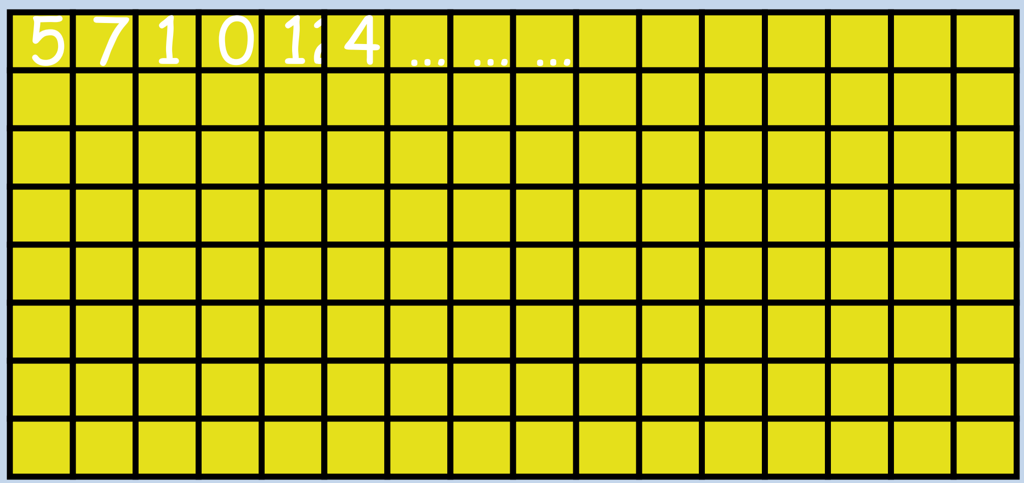
2D array of cells, modelling the cones/rods in natural eye



Each cell contains a numerical value (e.g. between 0-255 for 8 bit)

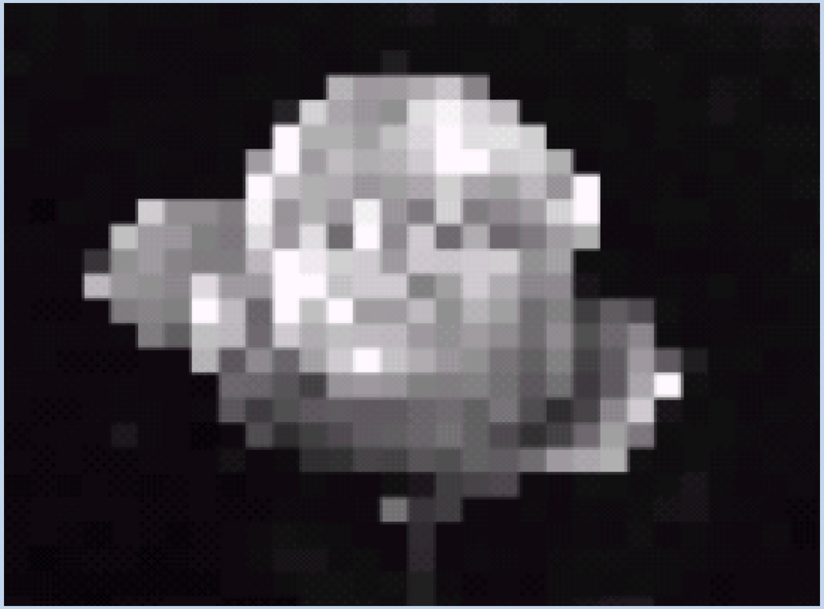
Digital images

- The *numerical value* of the cell represents the illumination received by the receptor



Digital images

- With this model, we can create GRAYVALUE images
- Value = 0: BLACK (no illumination / energy)
- Value = 255: White (max. illumination / energy)



Digital images

Usual Array Mathematatic can be Applied resulted into what is called enhanced image!

6	8	2	0
12	200	20	10

→

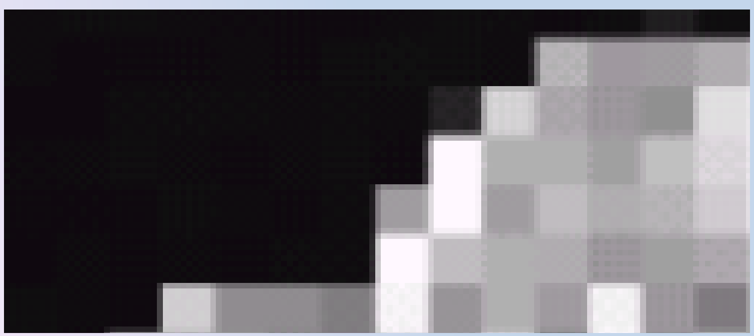
3	4	1	0
6	100	10	5

Digital images

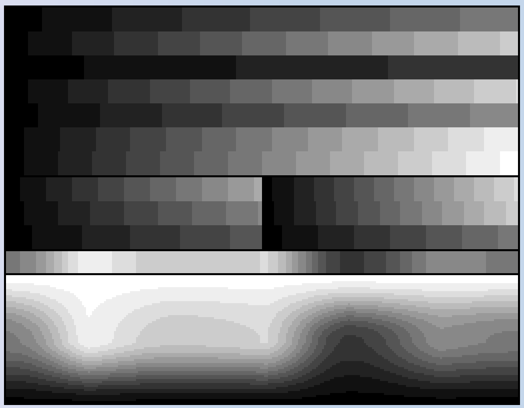
Remember: the value of the cells is the illumination (or brightness)

6	8	2	0
12	200	20	10

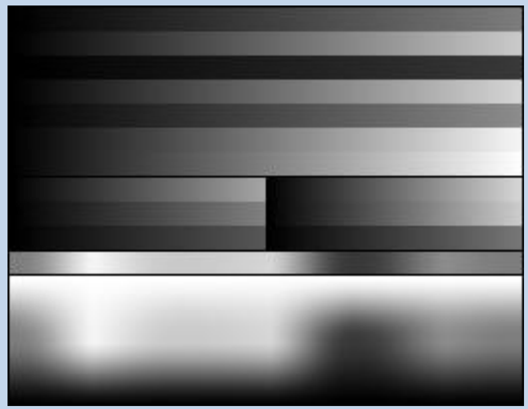
3	4	1	0
6	100	10	5



How many Bits your Camera /printer Have ?

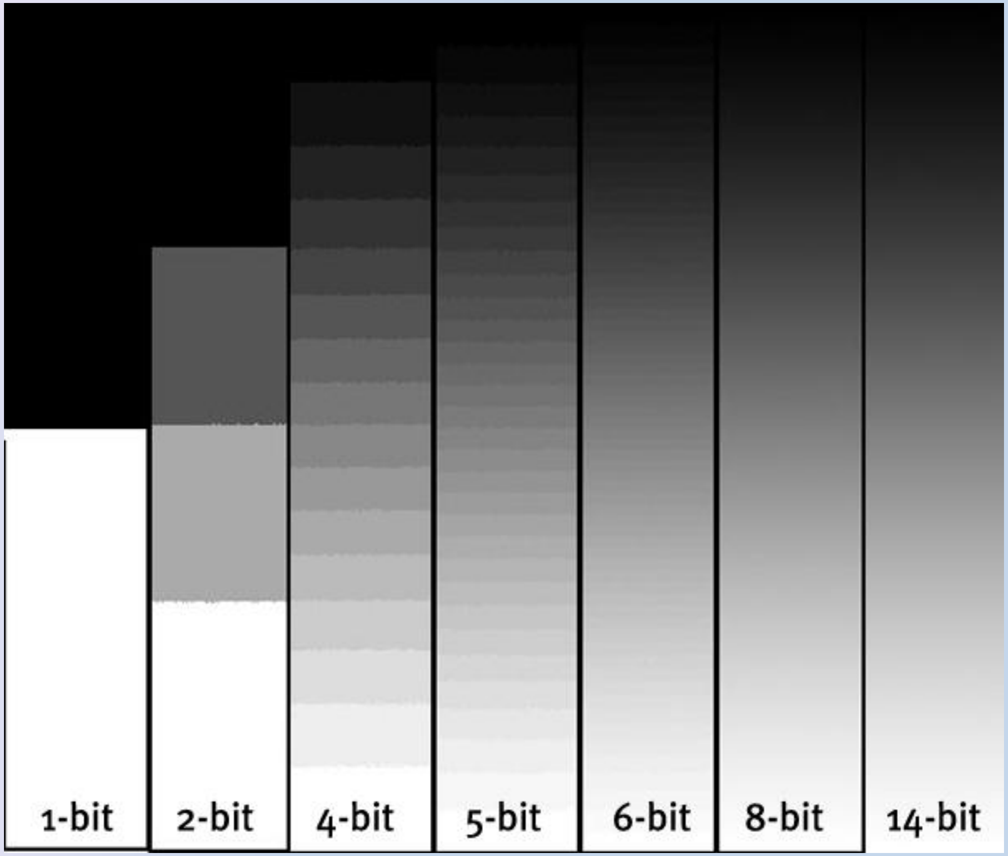


4 bits



8 bits

Digital images



$(X) = 2^Y$ (where Y equals the bit depth rating)

Bit Depth	Shades
1	2
2	4
4	16
6	64
8	256
10	1,024
12	4,096
14	16,384

Image Acquisition and Representation

Acquisition

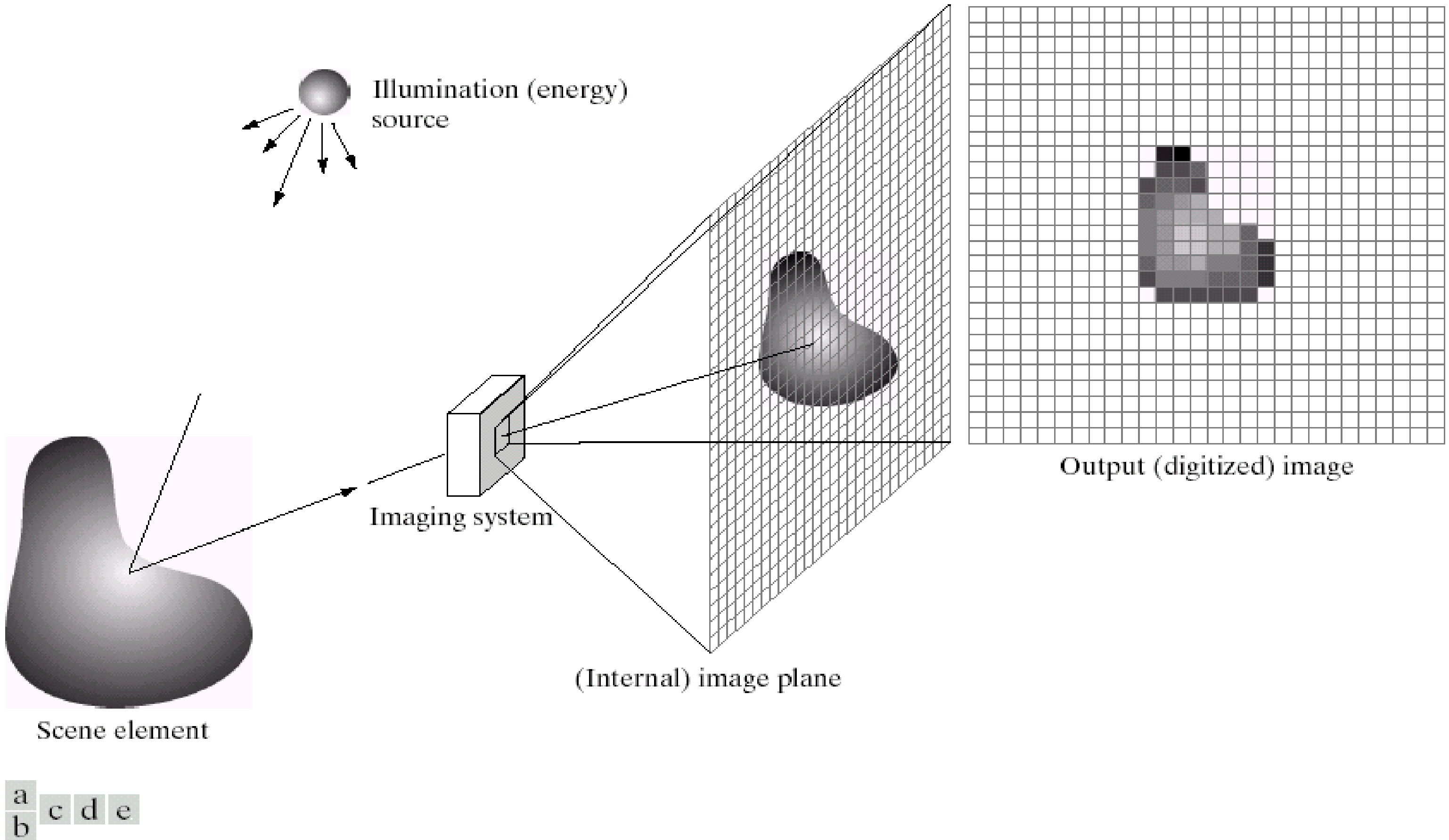


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

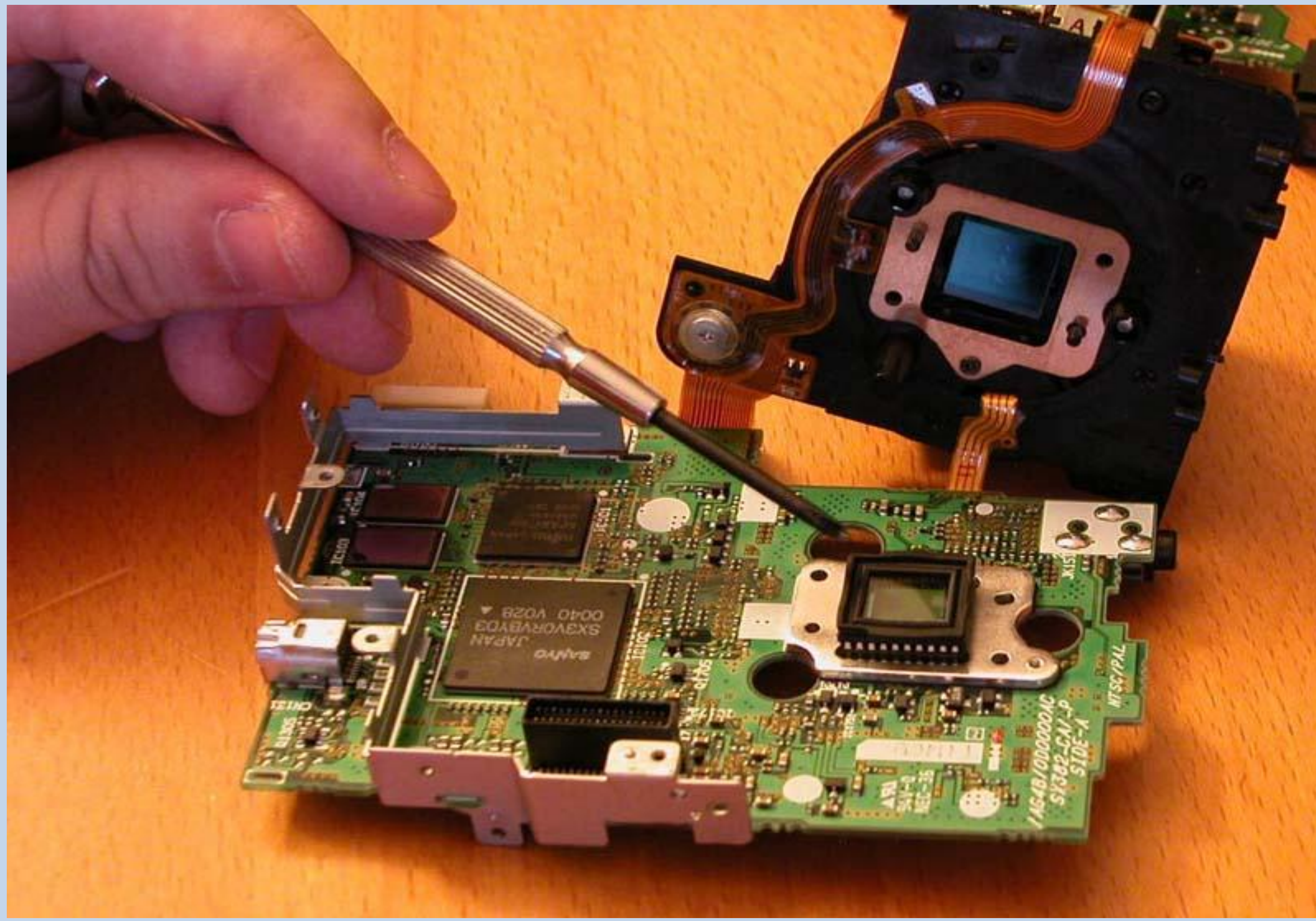
Digital images

Typical sensor for images:

CCD Array (Charge Couple Devices)

(invented in 1969 by Willard Boyle and George E. Smith)

Digital images

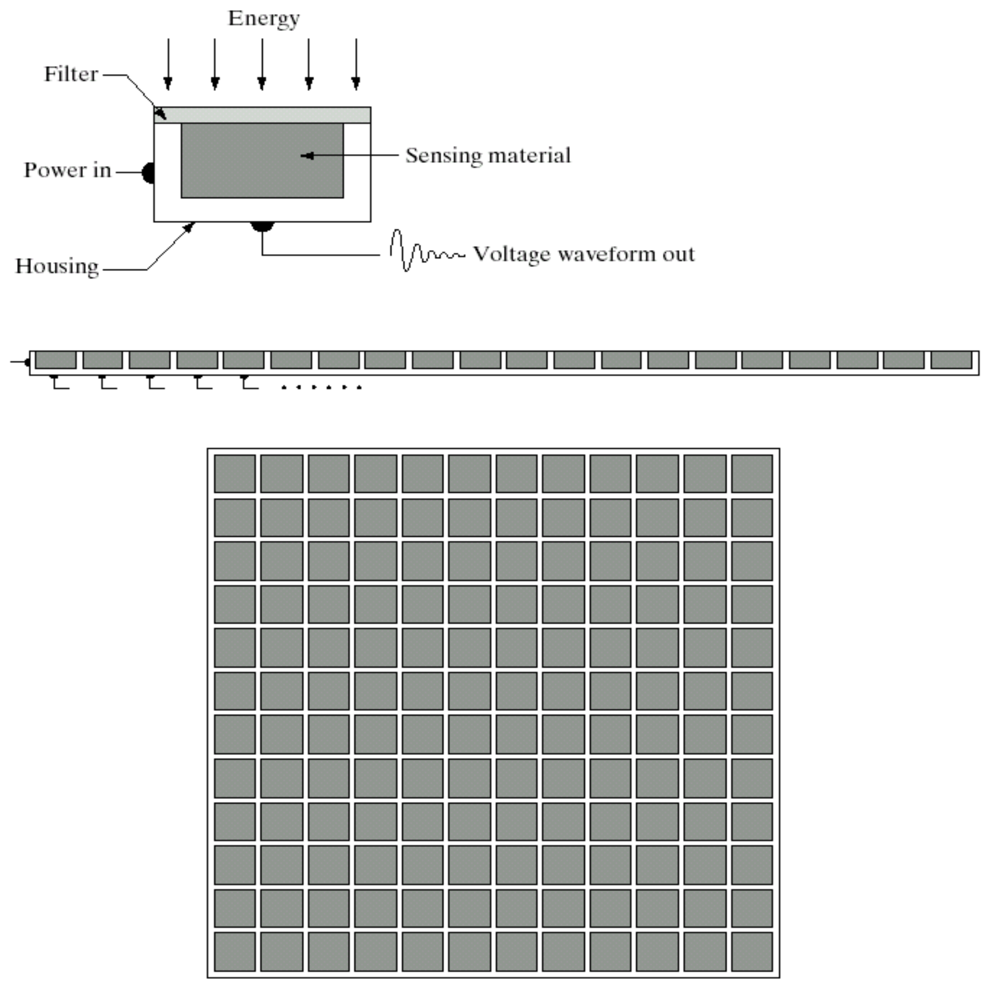


CCD Array (Charge Couple Devices)

10 millions Pixels and still increasing

Digital images

Acquisition



a b c

FIGURE 2.12 (a) Single imaging sensor. (b) Line sensor. (c) Array sensor.

Stepping down from Reality to INTEGER coordinates x,y: Sampling

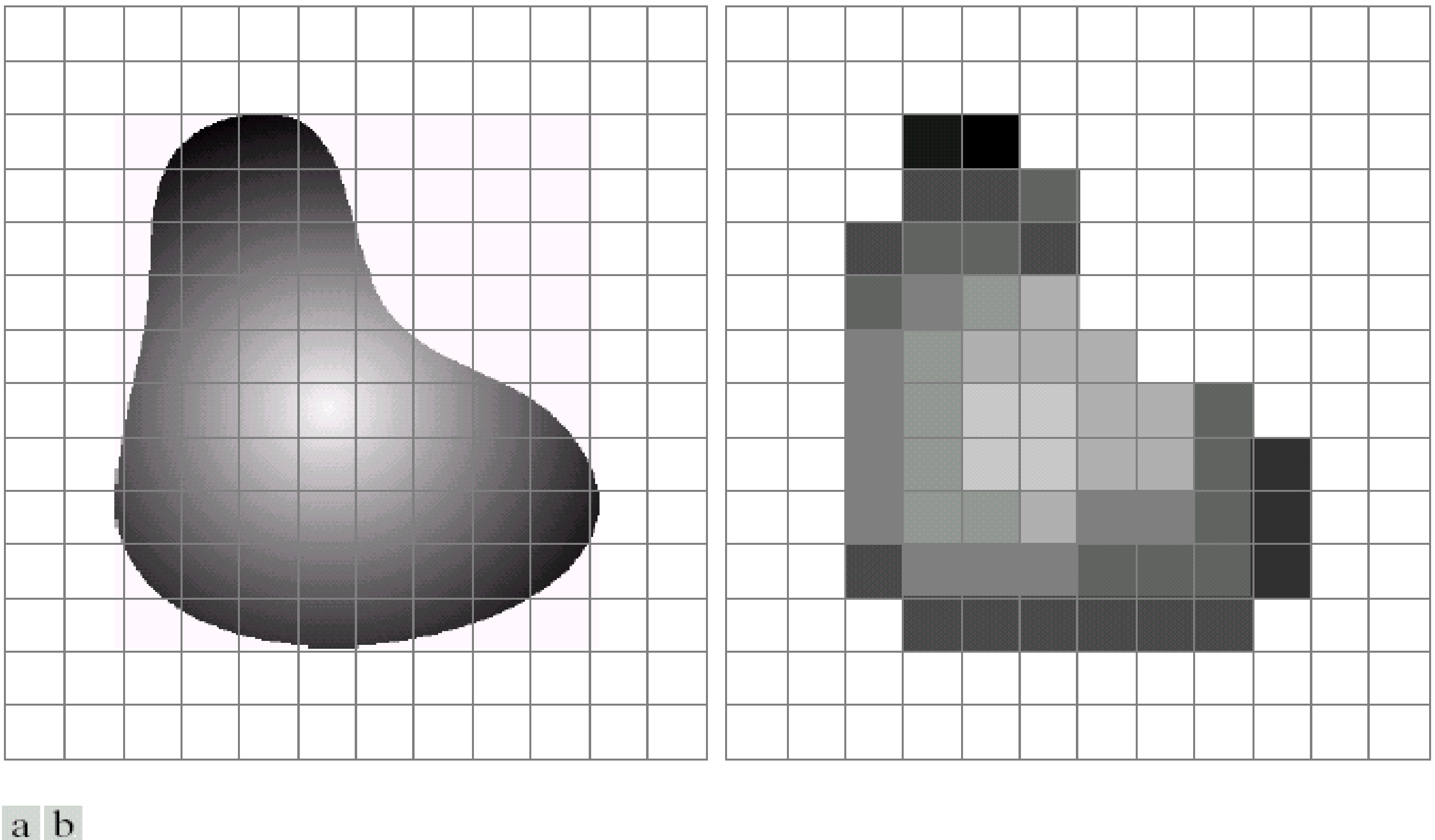
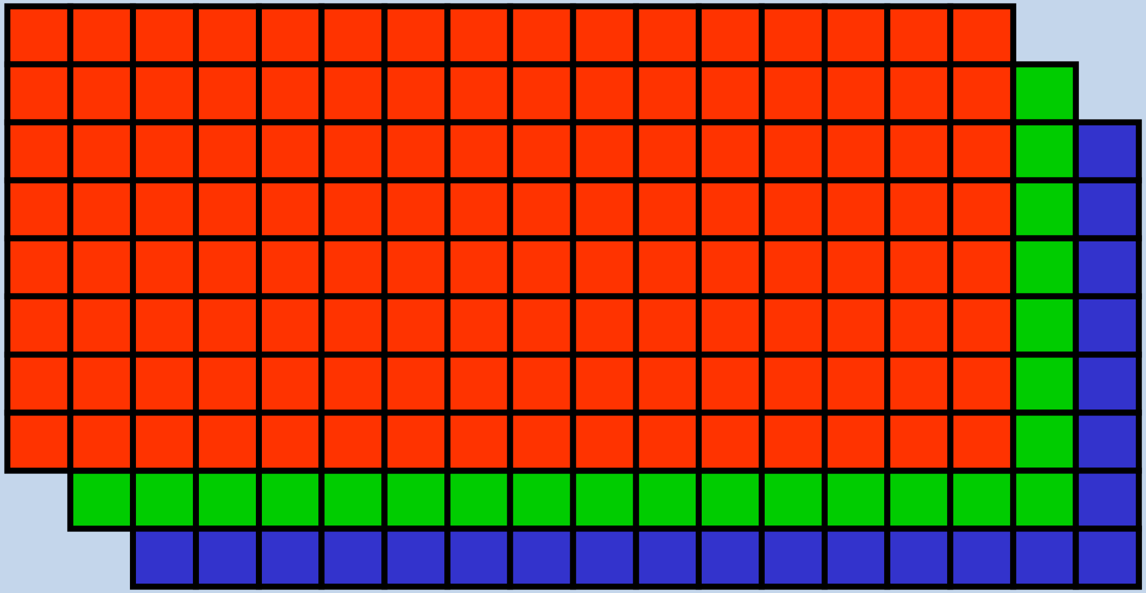


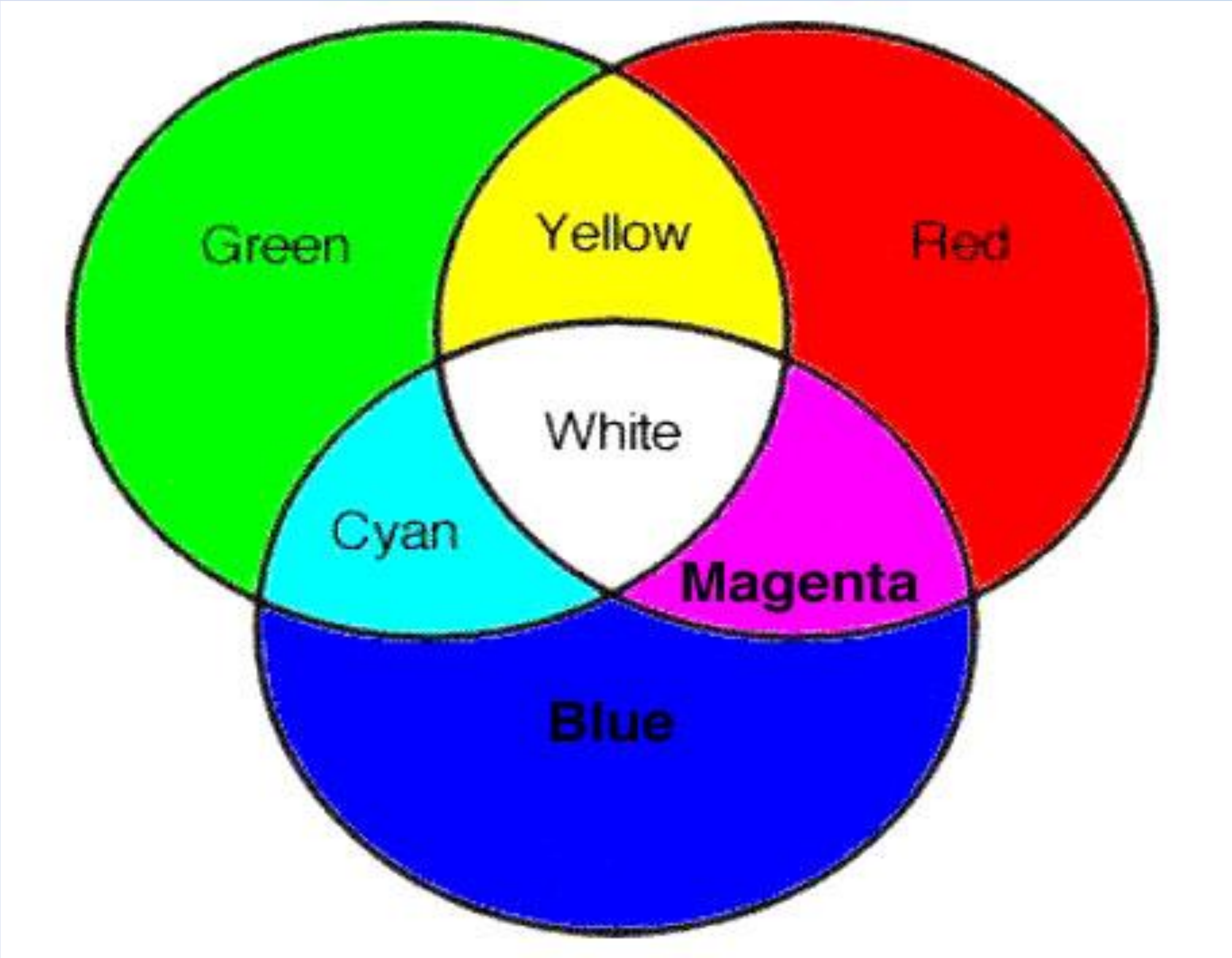
FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

Digital images

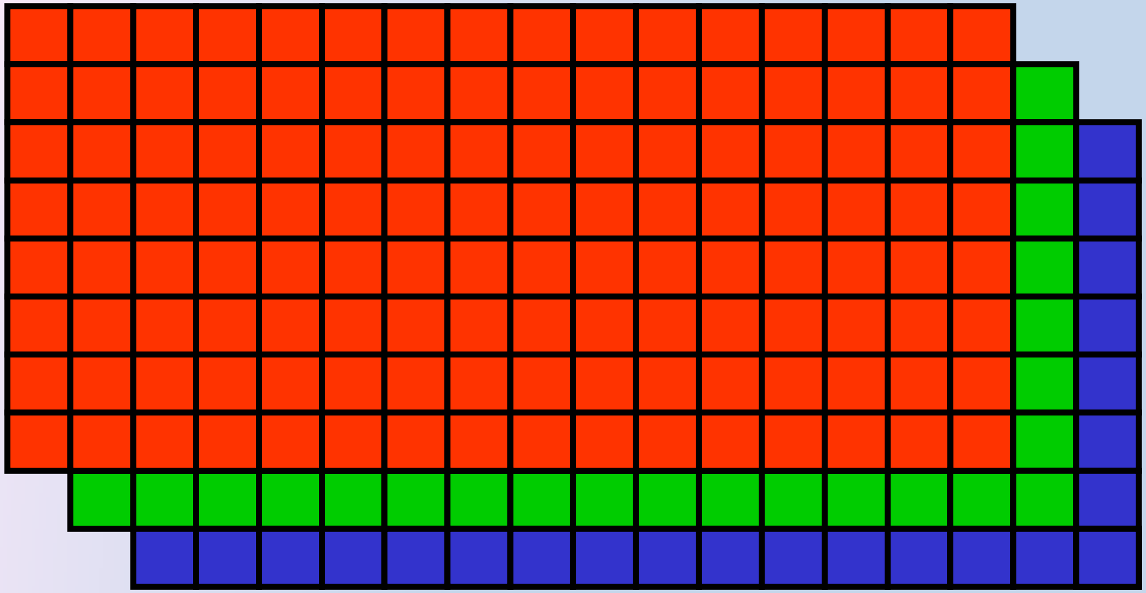
Color images can be represented by 3 Arrays (e.g. 320 x 240 x 3)

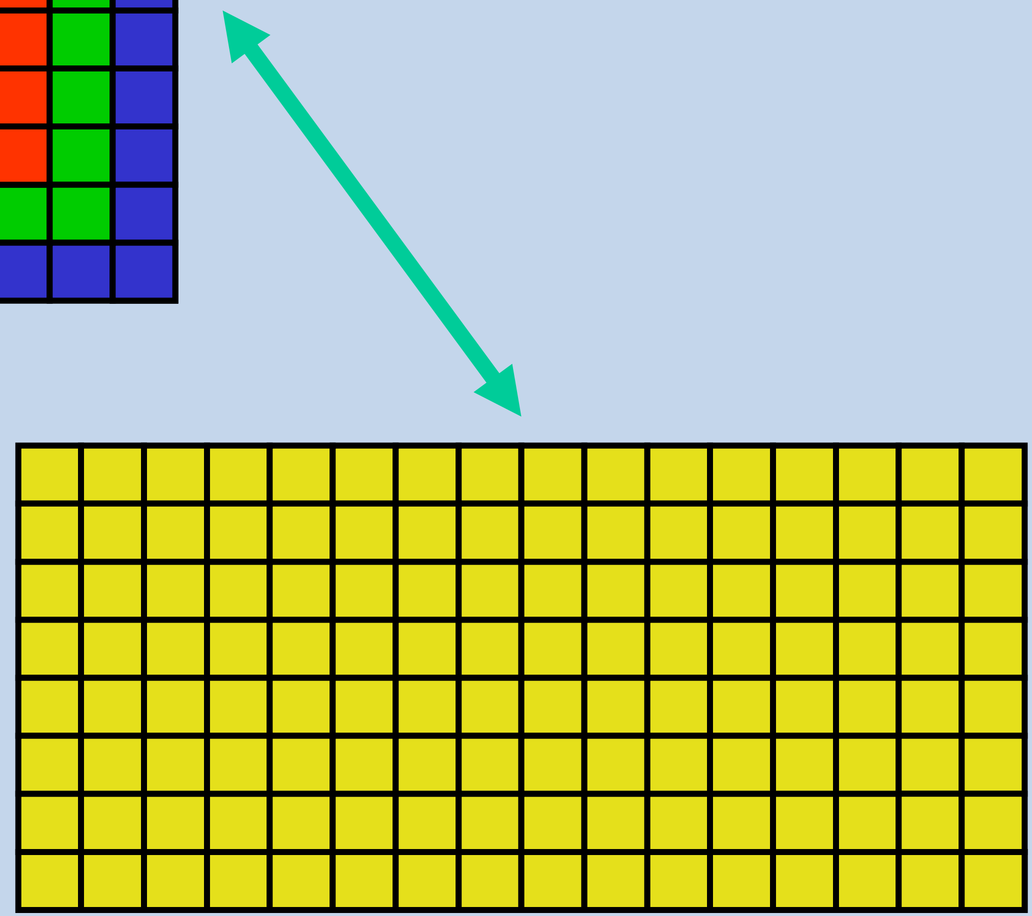


Physics of light
Additive colour mixing - light



Digital images

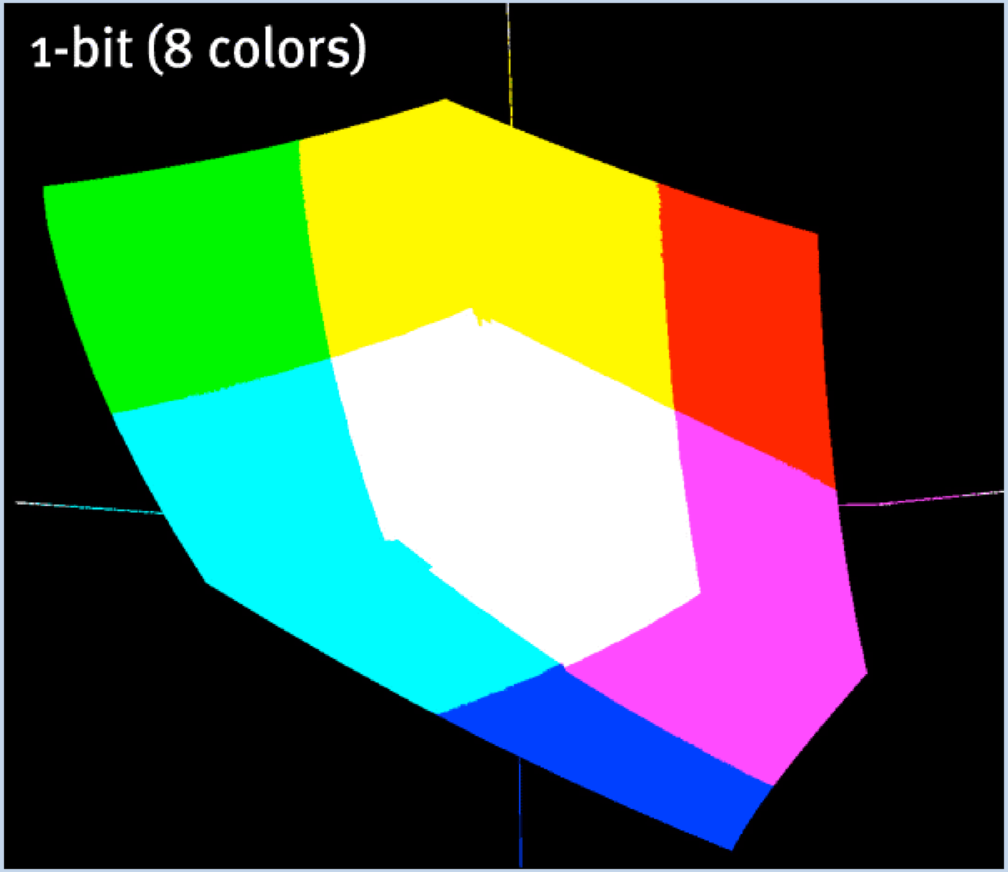




Corresponded pixels are added to form the coloured image

Digital images

Number of Colours= (X) = $(2^{Y})^{3}$ (where Y equals the bit depth rating)



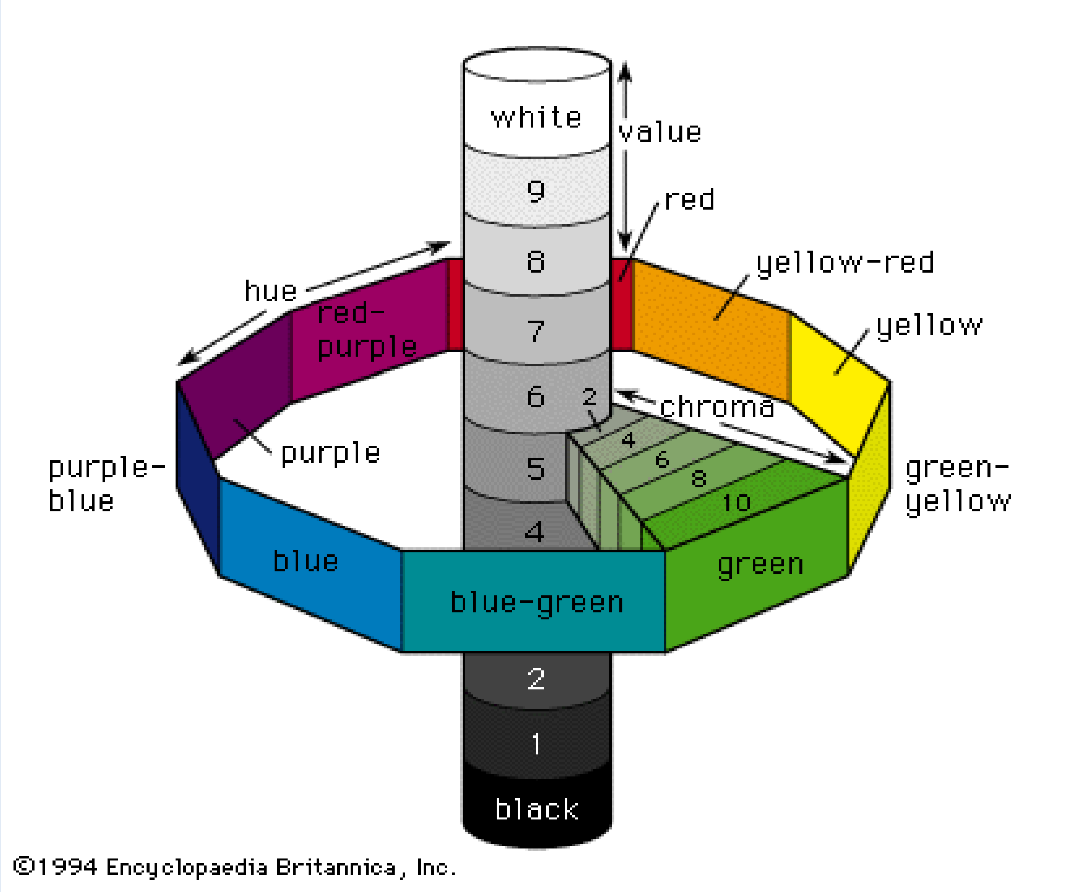
Colour Coding- Munsell Color System (1915)

➔Color = Hue + Value + Chroma

➔Hue	Basic color
➔Value	Brightness
➔Chroma	Saturation

(100 ,230,010)

Old coding but still used in art !



Colour Coding - CIE System (1931)

COMMISSION INTERNATIONALE DE L'ECLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION

- Based on visual perception measurements
- Basic principle
  - *Any* color stimulus can be matched *exactly* by a combination of three primary lights. Match is *independent of intensity*

R = 51

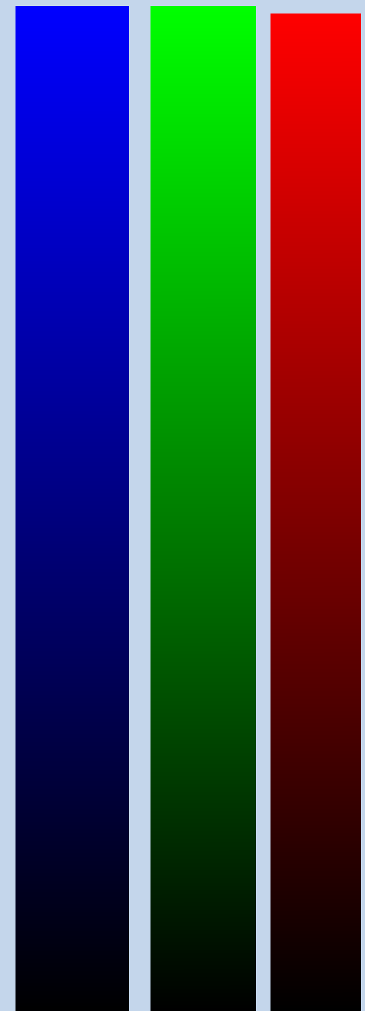
G =168

B =205

R = 255

G =255

B =255



Rendering of Remote Sensing Images

Rendering of individual IR channels

IR channels rendered either in:

- Physical mode - grey shades follow intensity of IR emission:
  ➔ brighter areas for stronger IR emission and darker areas for weaker IR emission

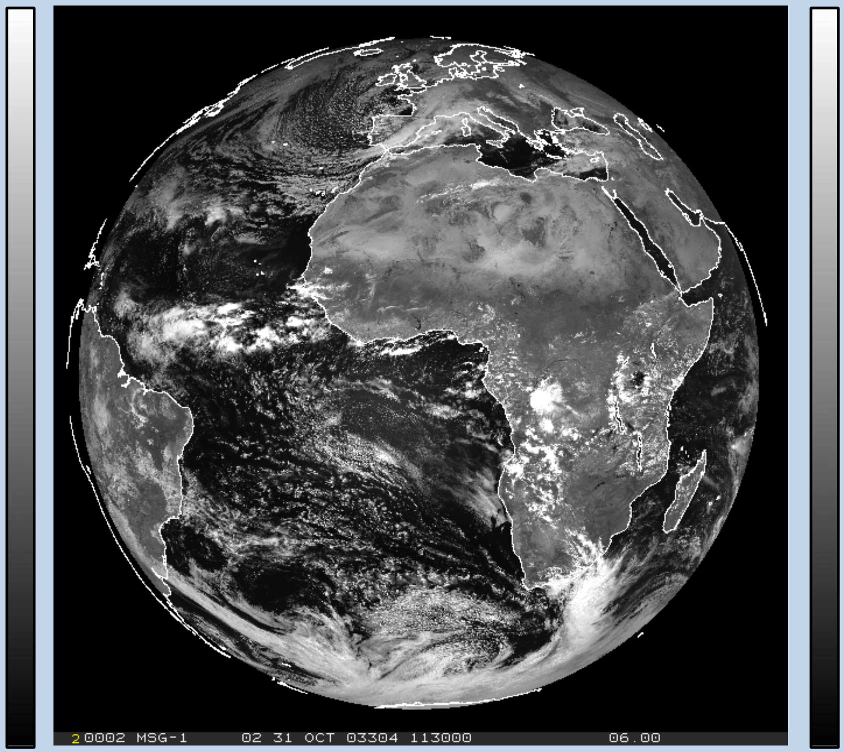
- Solar mode - inverted P mode (alternatively also annotated with letter “i” for “inverted”) :
  ➔ traditional mode, compares better to images from solar channels, i.e. clouds appears Bright instead of dark shades.

Rendering of individual channels - solar

solar: reflectivity
(P mode only)

high

low



clouds

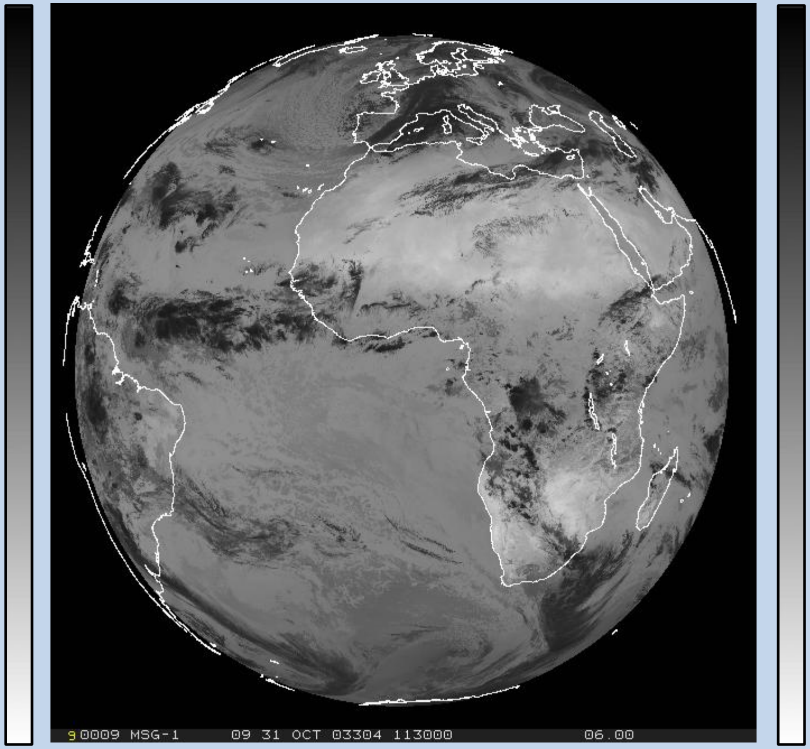
land / sea

Rendering of IR channels

IR: emission / brightness temperature
Physical mode

weak / cold

strong / warm



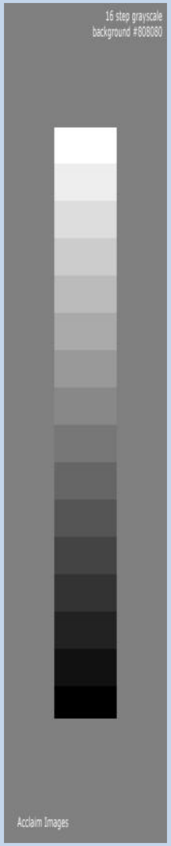
clouds / more absorption

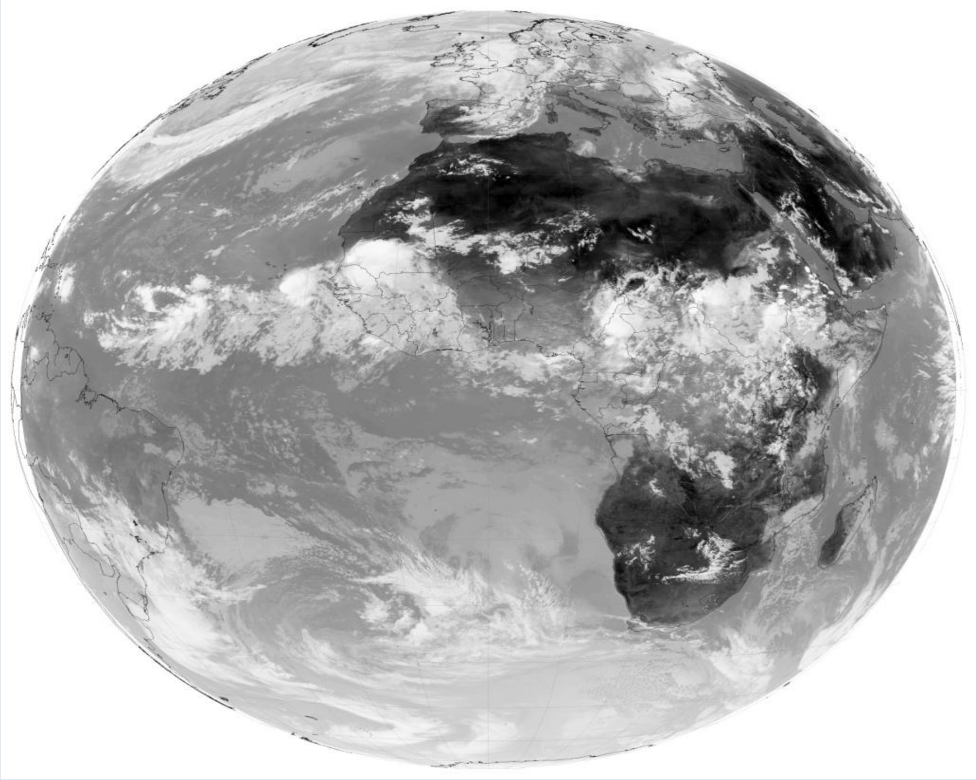
land / sea / less absorption

Rendering of IR channels

IR: emission / brightness temperature
S mode

Bright/weak / cold





Dark/strong / warm

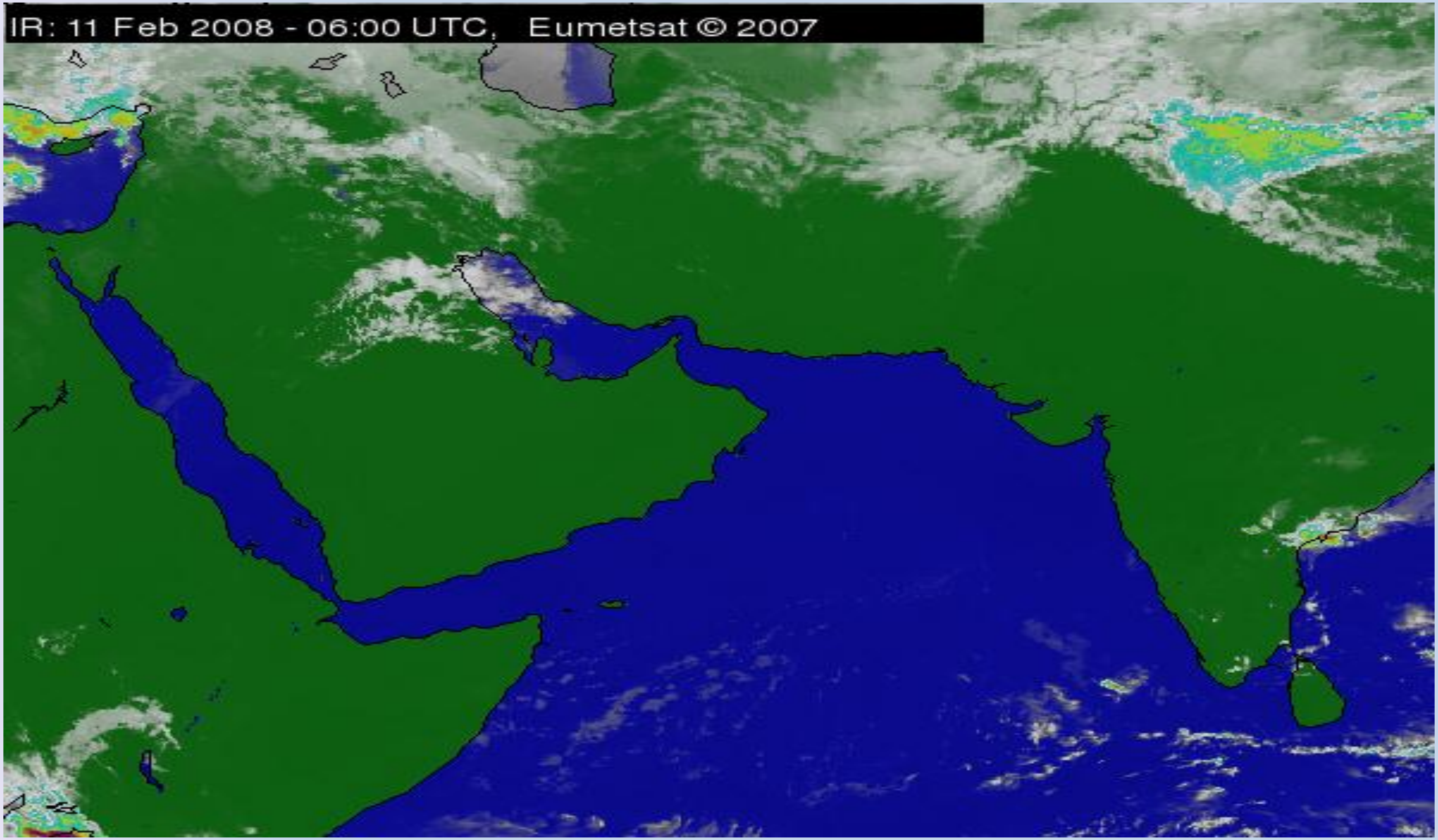
Feature enhancement

Feature Enhancement methods

1. simple grey scale
2. Difference of Two Channels
3. Look Up Table (LUT) for pseudo colours
4. RGB composites by attributing 2 to 3 channels or channel combinations to individual colour

LUT – lookup table

- Table allowing a display system to map pixel values into colours or grey scale values with a convenient range of brightness and contrast.

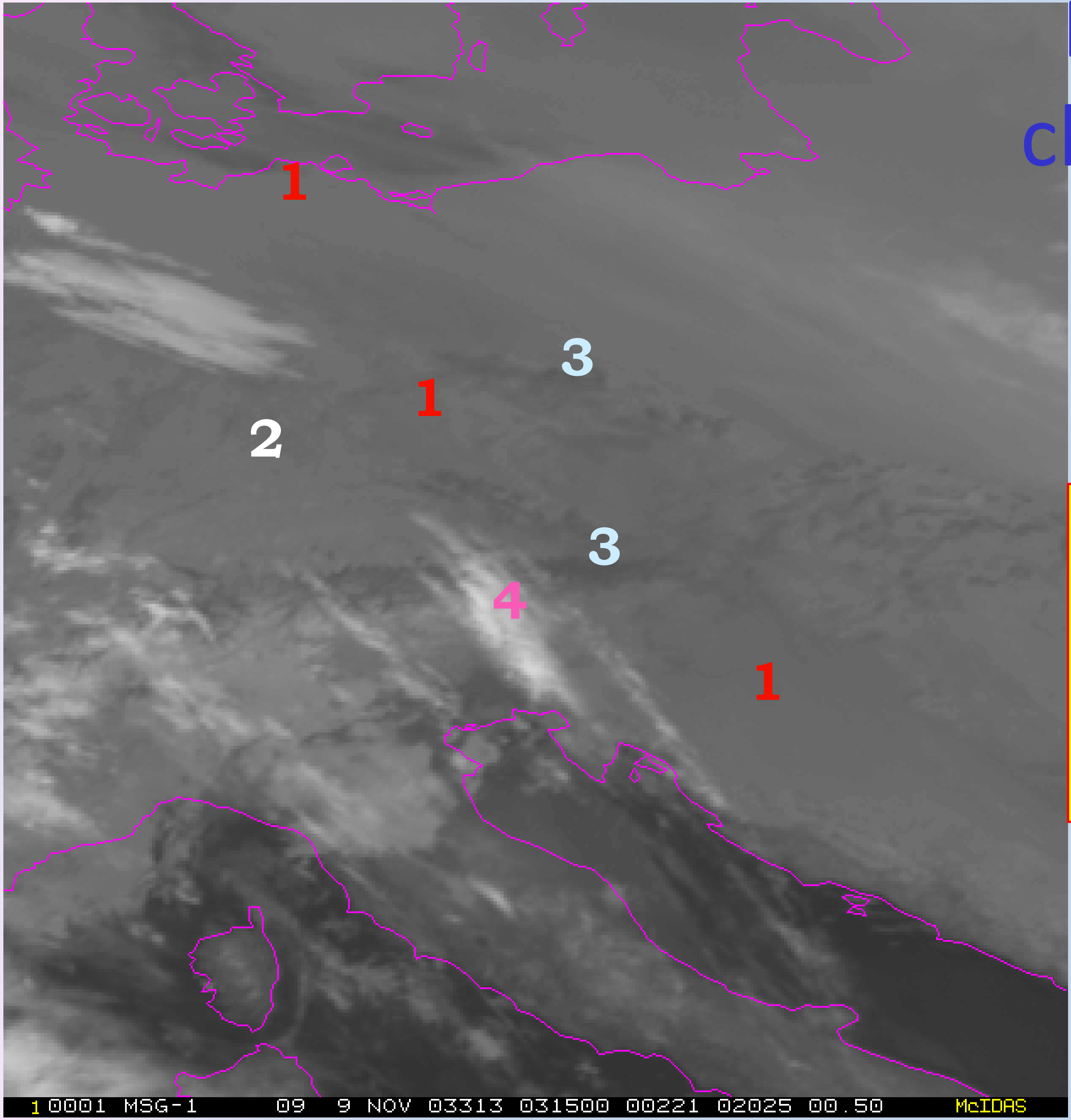


Differences of 2 channels

- **Clouds**
  - 03-01
  - 04-09
  - 05-06
  - 05-09
  - 06-09
- **Thin cirrus**
  - 07-09
  - 04-09
  - 10-09
- **Fog**
  - 09-04
  - 09-07
- **Snow**
  - 03-01
- **Volcanic ash (SO2)**
  - 06-11
- **Dust**
  - 04-09
  - 07-09
  - 10-09
- **Vegetation**
  - 02-01
- **Fire**
  - 04-09
- **Smoke**
  - 03-01

More on recommended differences and their interpretation in other chapters of the Guide

Differences of 2 channels-Example



Fog at night not visible in IR window channels

1= low-level fog or stratus

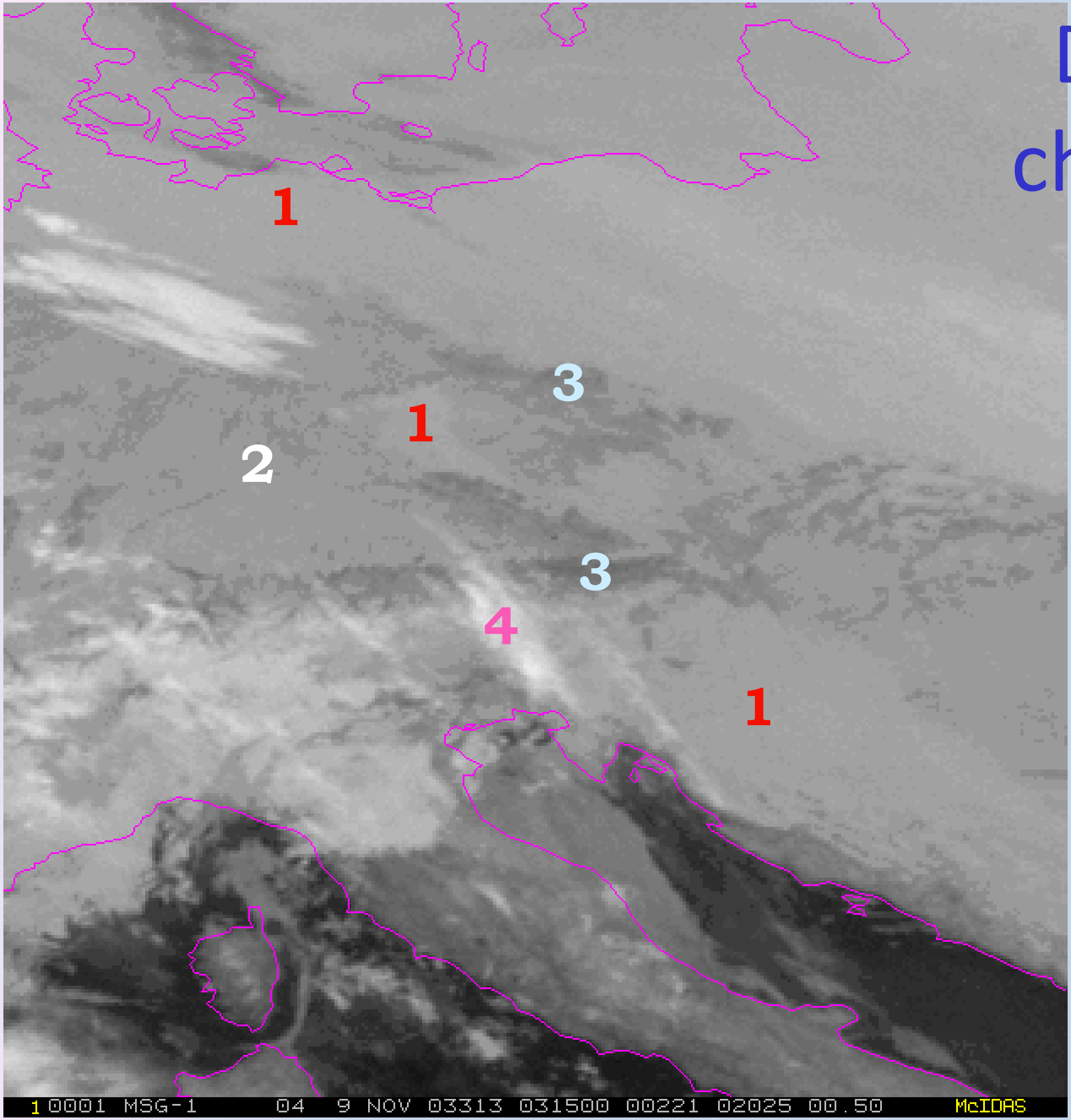
2= cold clear ground

3 = warm clear ground (mountains)

4 = thin, high-level clouds

MSG-1
09 November 2003
03:15 UTC
Channel 09
(IR10.8)

Differences of 2 channels-Example



Fog at night not visible in IR window channels

1= low-level fog or stratus

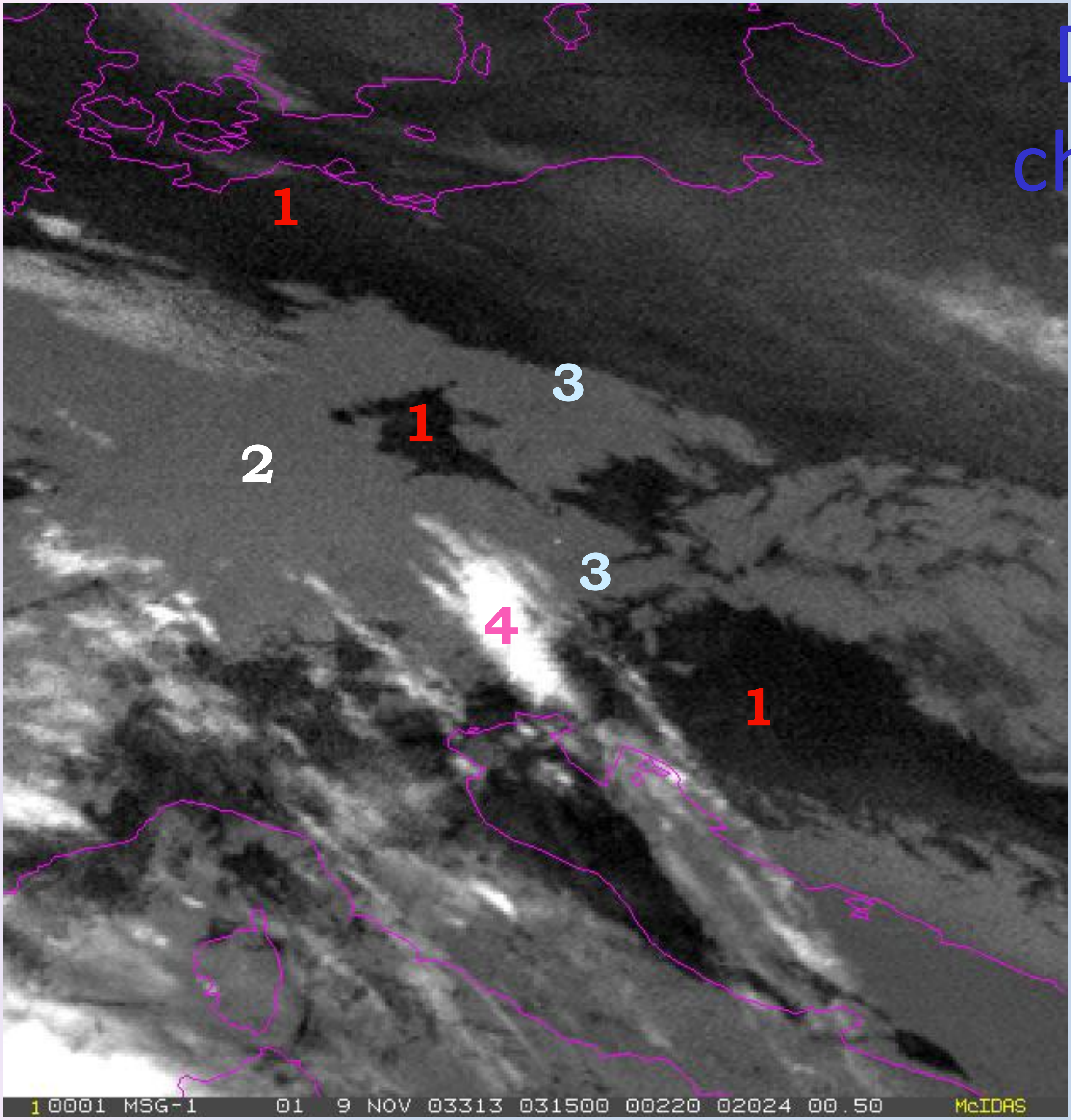
2= cold clear ground

3 = warm clear ground (mountains)

4 = thin, high-level clouds

MSG-1
09 November 2003
03:15 UTC
Channel 04
(IR3.9)

Differences of 2 channels-Example



Fog at night visible in IR3.9 - IR10.8 difference images

Fog: -7/-10 K (black)
Ground: -4/-5 K (grey)

1= low-level fog or stratus

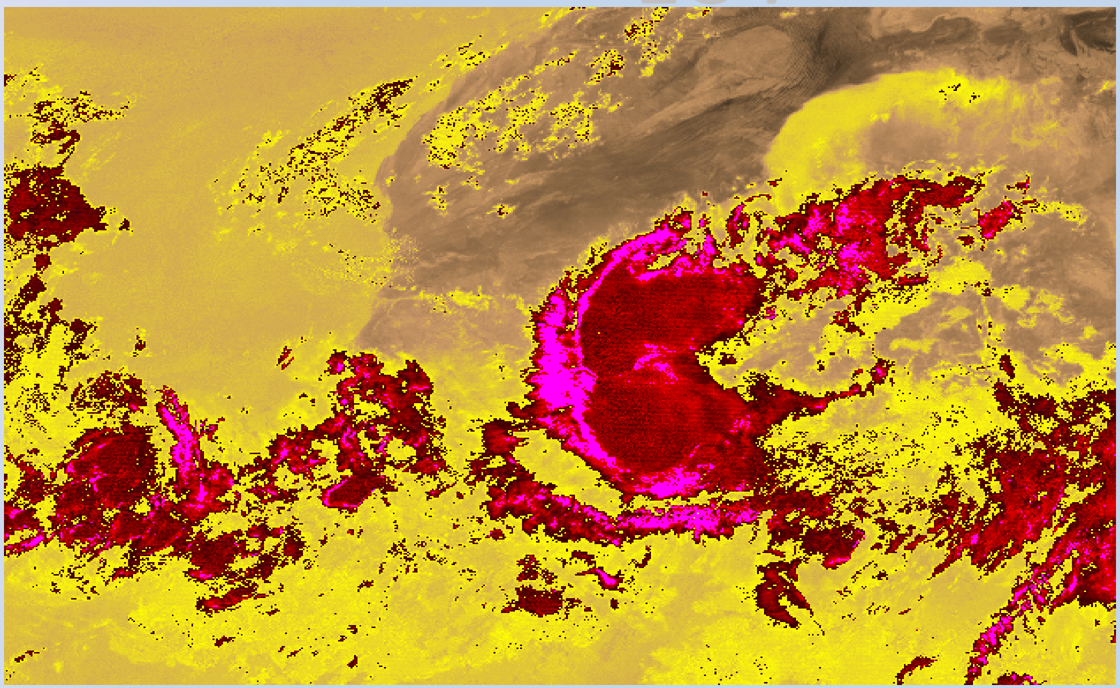
2= cold clear ground

3 = warm clear ground (mountains)

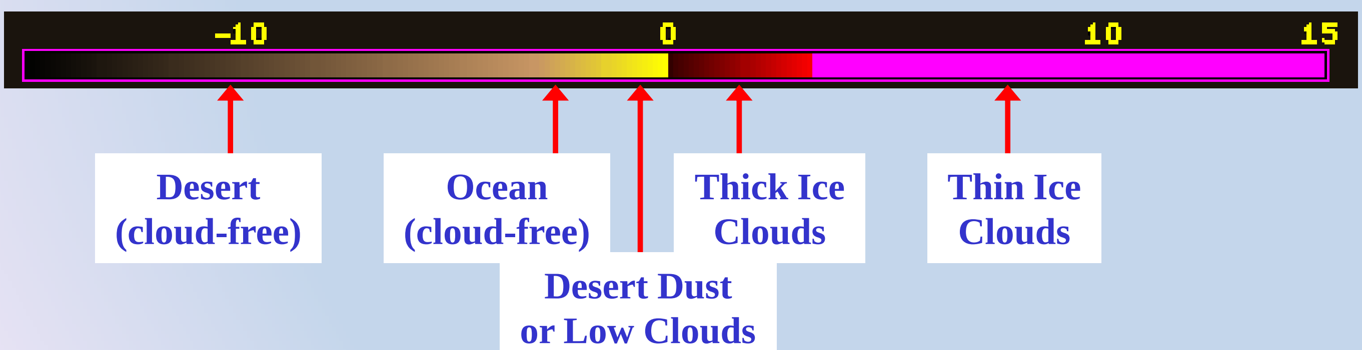
4 = thin, high-level clouds

MSG-1
09 November 2003 03:15 UTC
Difference Image
IR3.9 - IR10.8

Differences of 2 channels – using colour LUT



09 – 04
ice / low clouds
desert dust



RGB image composites

is defined as attribution of images of 2 or 3 channels (channel combination) to an individual colour (RGB) beam of a display device;

RGB image composites

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

➔FAST BUT QUITE EFFICIENT SURROGATE FOR QUANTITATIVE FEATURE EXTRACTION

RGB image composites – how to do

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

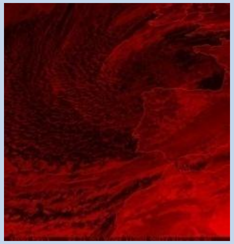
- Selection of either P or S mode for IR channels.
- Proper Channel's Enhancement
- Good selection of the ranges ;
- Proper enhancement of individual colour channels (Gamma factor)

Gamma factor: A factor used to increase or decrease the contribution of a certain colour Gun

In a RGB product, Physical mode is used unless indicated by letter (i) or (r)

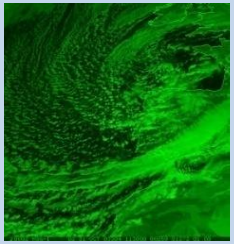
RGB image composites

Channel 03



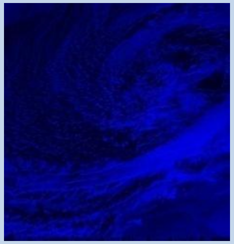
+

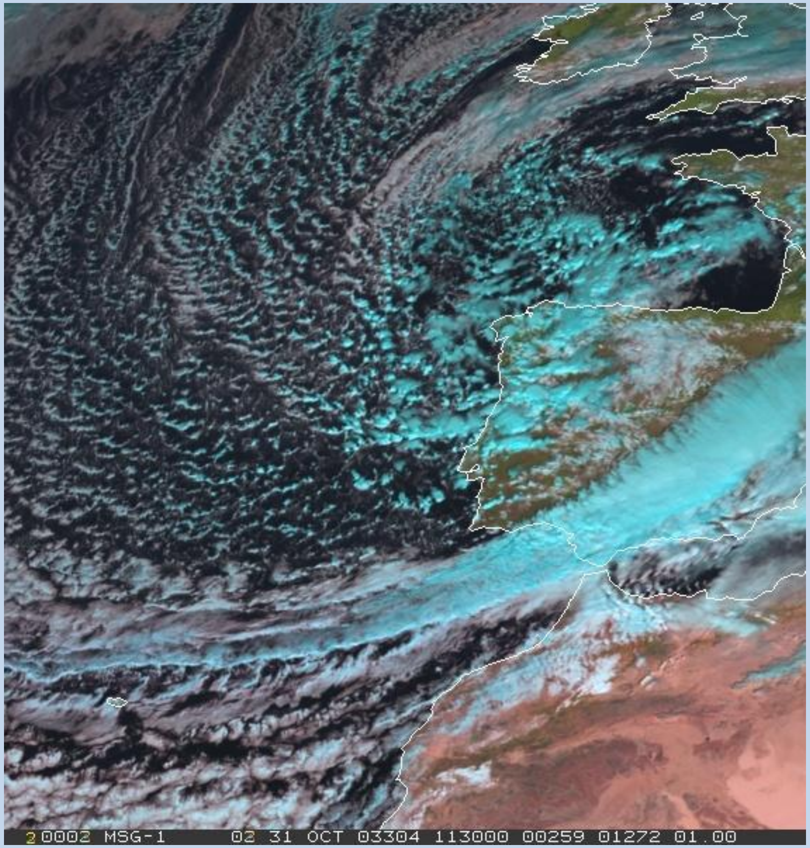
Channel 02



+

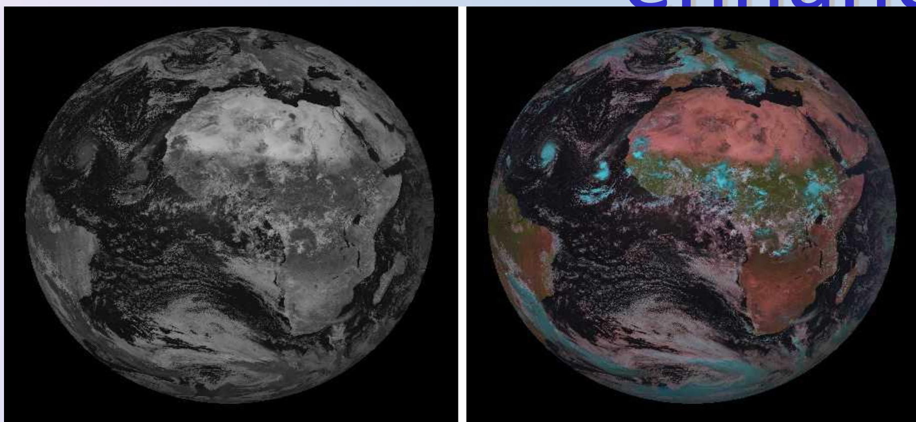
Channel 01



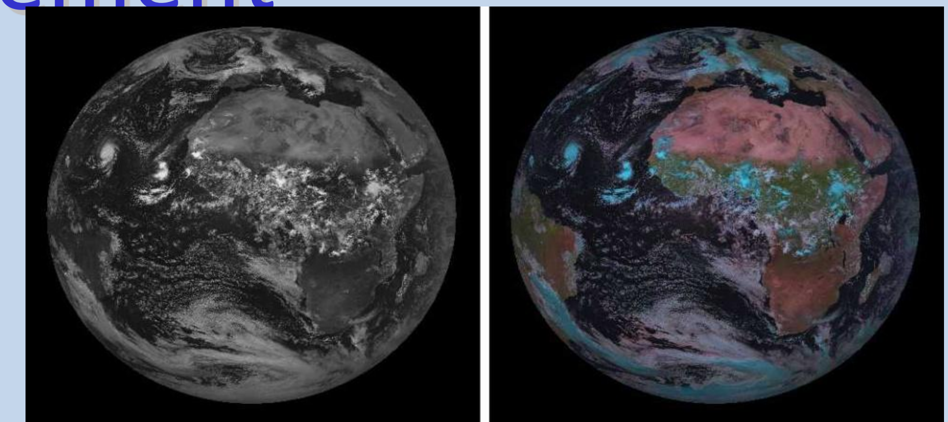


Color Selector.exe

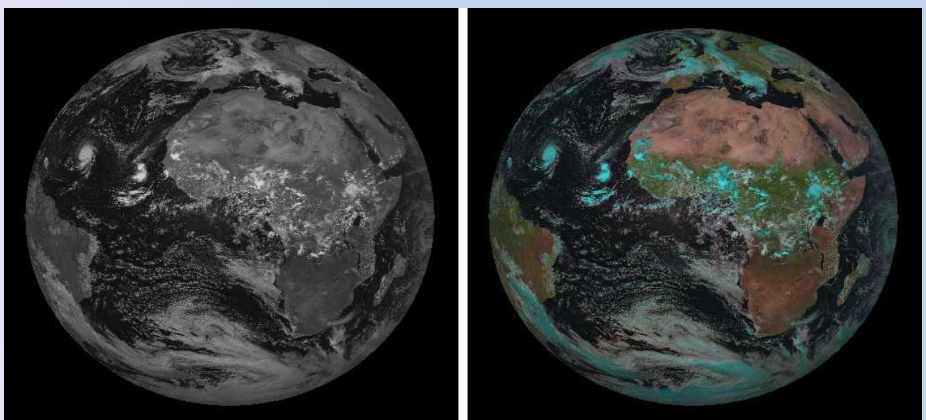
RGB image composites – varying enhancement



red



blue



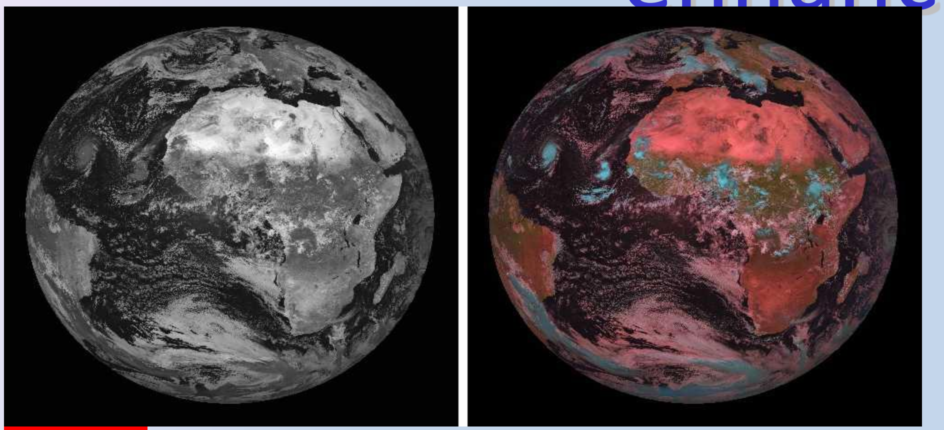
green

observe increasing enhancement of individual RGB colour planes on the left and resulting colour shades to the right of each image couple

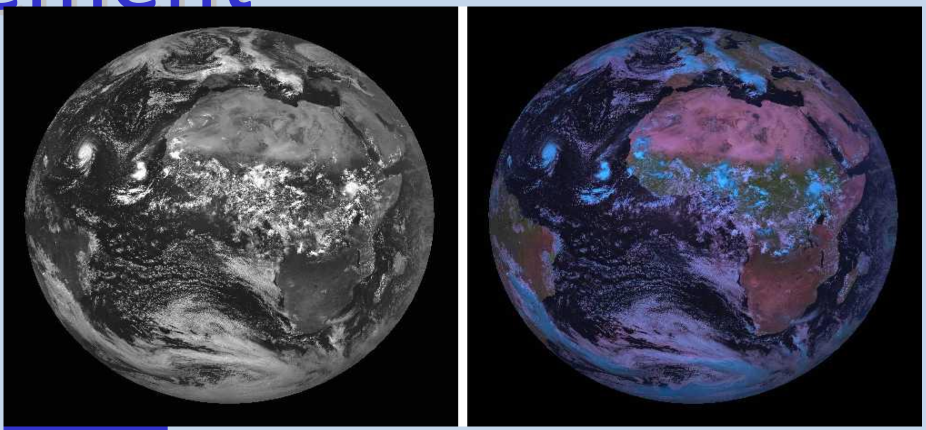
in 5 steps

1

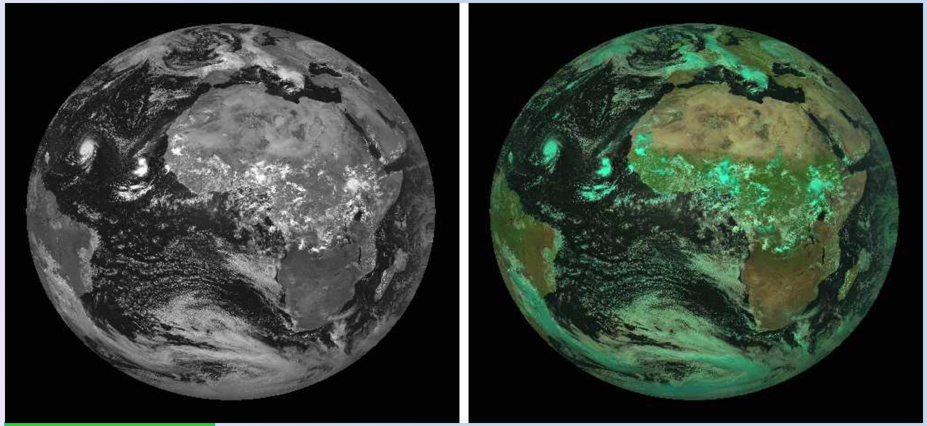
RGB image composites – varying enhancement



red



blue

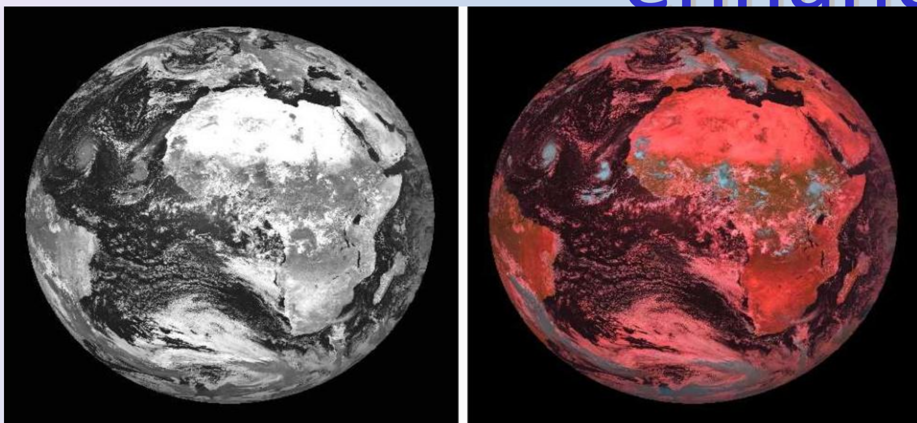


green

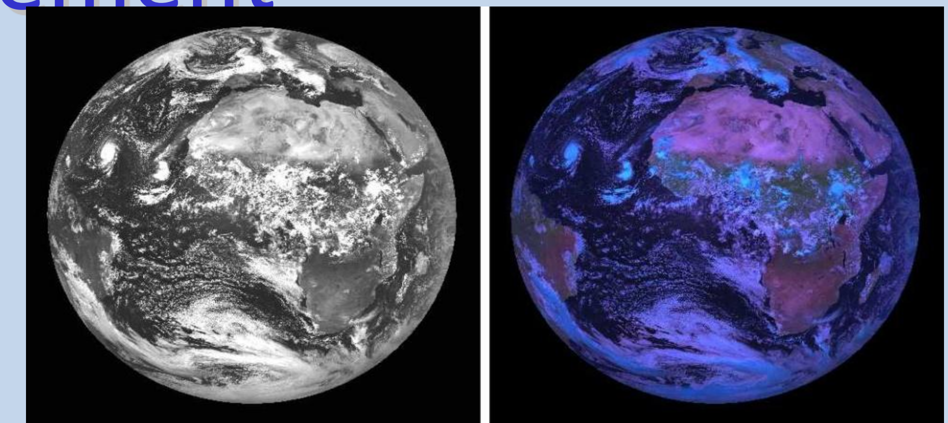
observe increasing enhancement of individual RGB colour planes on the left and resulting colour shades to the right of each image couple

in 5 steps 2

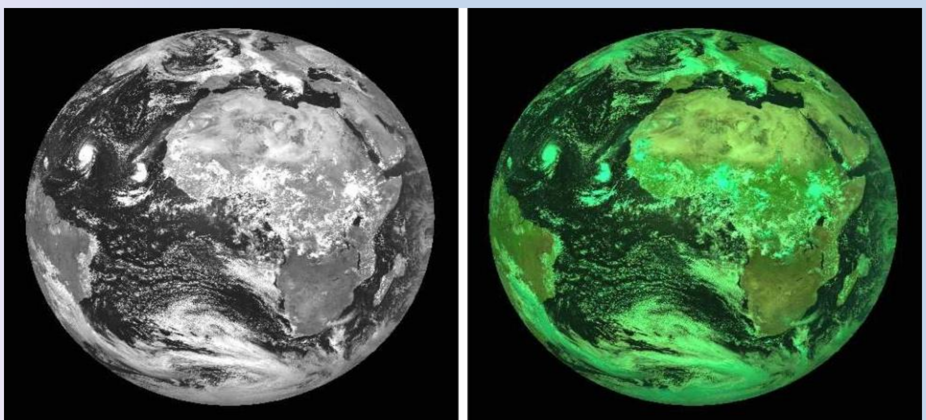
RGB image composites – varying enhancement



red



blue



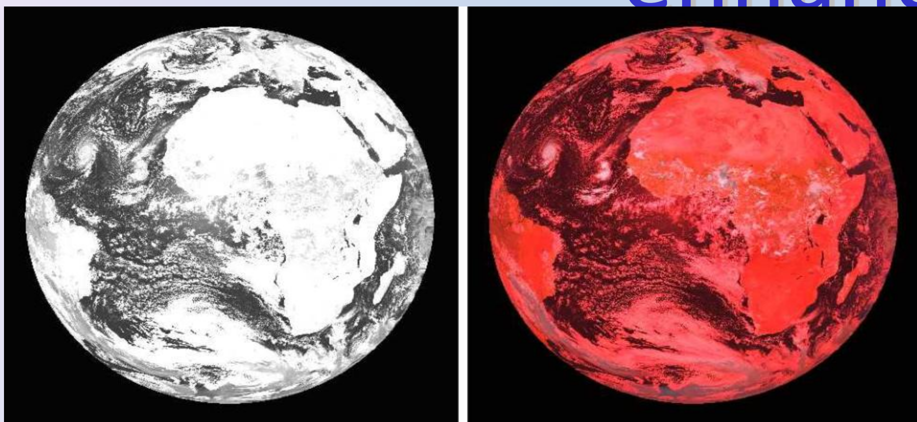
green

observe increasing enhancement of individual RGB colour planes on the left and resulting colour shades to the right of each image couple

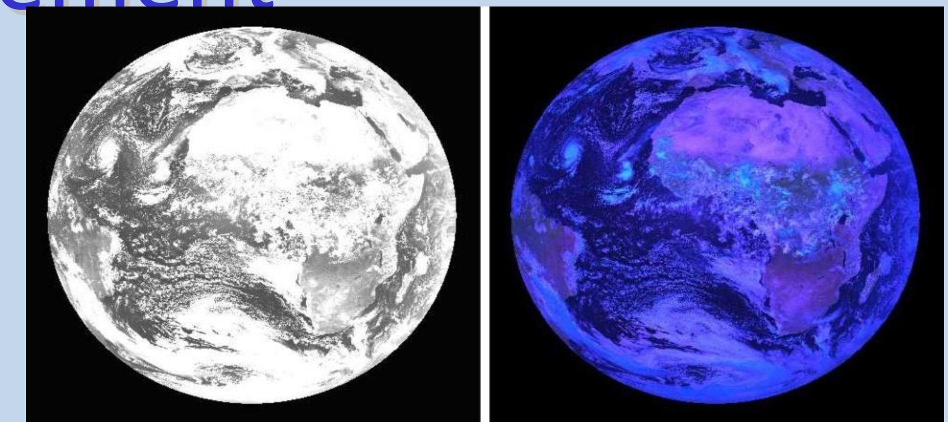
in 5 steps

3

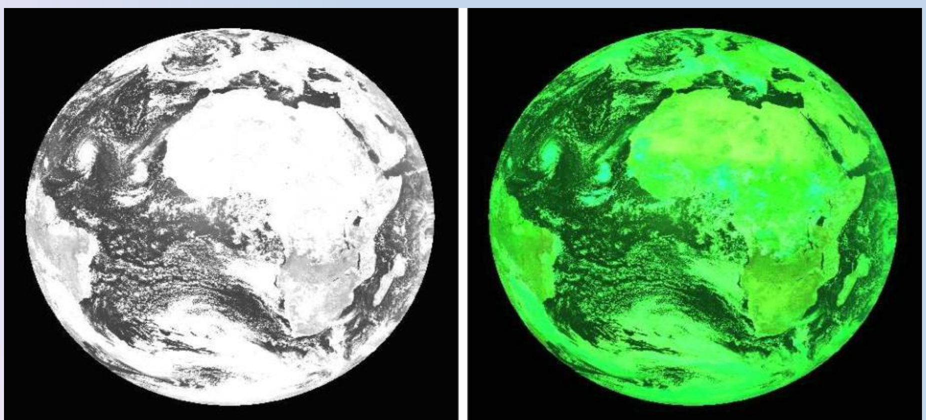
RGB image composites – varying enhancement



red



blue



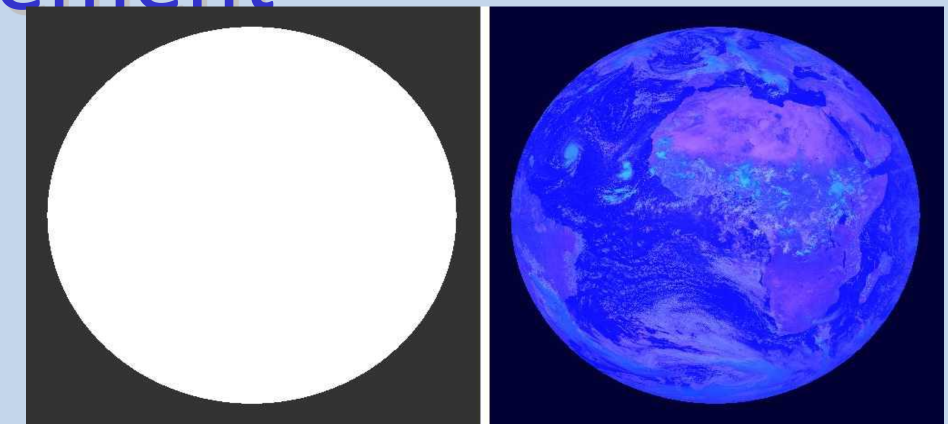
green

observe increasing enhancement of individual RGB colour planes on the left and resulting colour shades to the right of each image couple

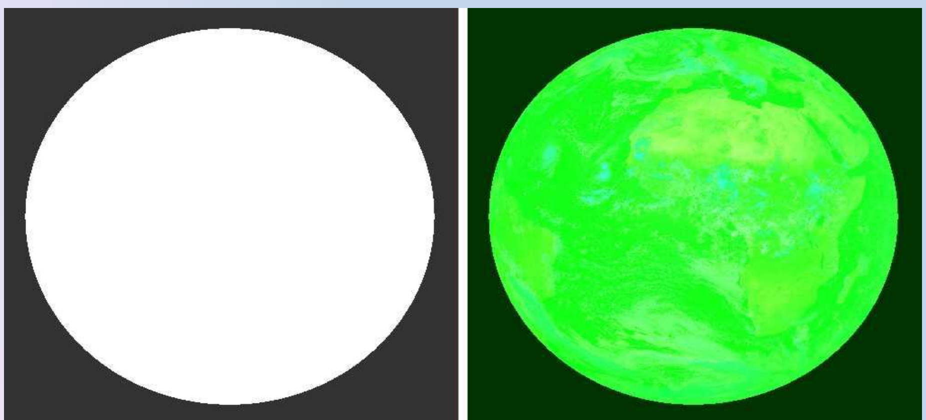
in 5 steps 4

RGB image composites – varying enhancement

red



blue



green

observe increasing enhancement of individual RGB colour planes on the left and resulting colour shades to the right of each image couple

in 5 steps 5

Example for Range and Gamma selection

Different selection of Range and Gamma factor result in different RGB

R = IR12.0 - IR10.8

G = IR10.8 - IR8.7

B = IR10.8

Applications:	Clouds, Contrails, Dust, Ash, SO2, Low-level Humidity
Area:	Full MSG Viewing Area
Time:	Day and Night
Users:	most European & African NMSs, Middle East

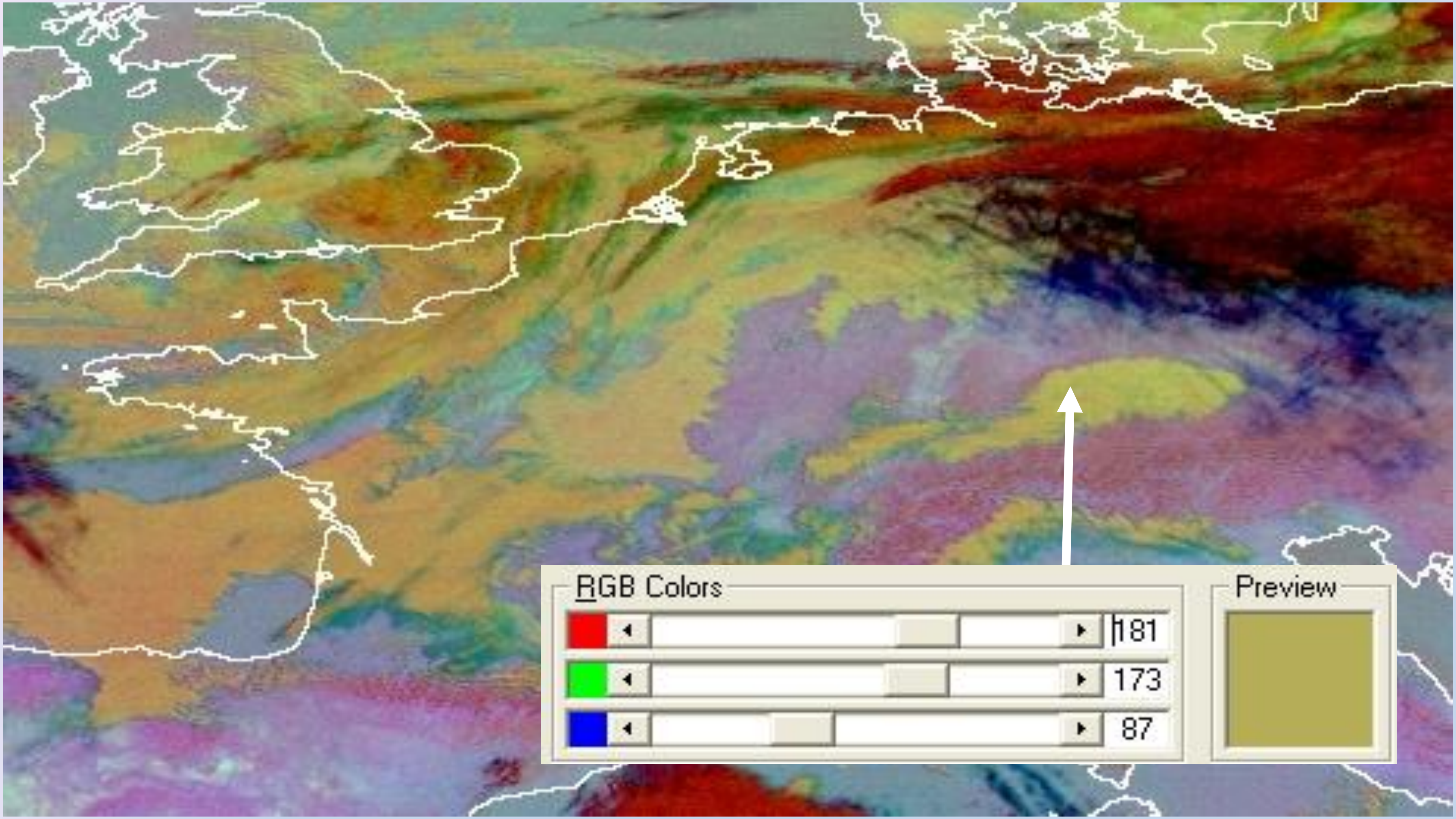
Example for Range and Gamma selection

RGB 10-09, 09-07, 09
("24-hour Cloud Microphysics")

Recommended Range and Enhancement:

Beam	Channel	Range	Gamma
Red	IR12.0 - IR10.8	-4 ... +2 K	1.0
Green	IR10.8 - IR8.7	0 ... +6 K	1.2
Blue	IR10.8	+248 ... +303 K	1.0

Example for Range and Gamma selection



MSG-1, 17 February 2004, 12:00 UTC

ClEAR DISTENCTION BETWEEN CLOUDS

Example for Range and Gamma selection

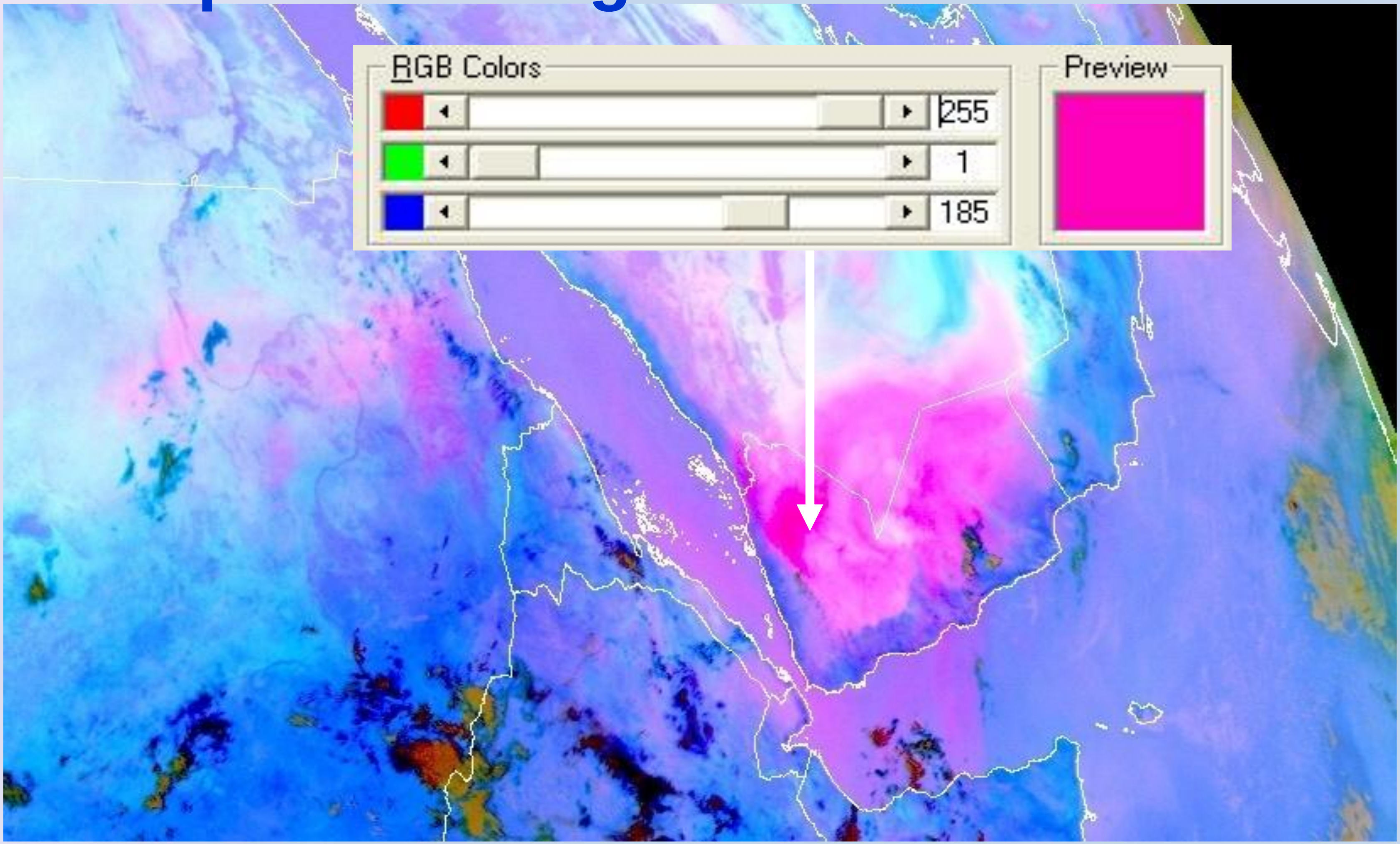
RGB 10-09, 09-07, 09
(“24-hour Dust Microphysics")

devised by: D. Rosenfeld

Recommended Range and Enhancement:

Beam	Channel	Range	Gamma
Red	IR12.0 - IR10.8	-4 ... +2 K	1.0
Green	IR10.8 - IR8.7	0 ... +15 K	2.5
Blue	IR10.8	+261 ... +289 K	1.0

Example for Range and Gamma selection



MSG-1, 14 June 2006, 08:00 UTC

Example: Dust (Day)

RGB image composites

- Convection
  - 01,03,09
    01,03,10
  - 01,04,09
    01,04,10
  - 03,04,09
    03,04,10
- HRV (channel)
  - 12,12,04
  - 12,12,09
  - 12,12,03

More on recommended composites and their interpretation in 00_rgb_part[04/05/06].ppt

- Dust
  - 01,03,04
  - 03,02,01
- Vegetation
  - 03,02,01
- Fire/Smoke
  - 03,02,01
  - 04,02,01
- Generic operational
  - AIMASS
  - DUST
  - FOG (night time microphysics)

Question to ask yourself before interpretation of an RGB image

1- what channel is it?
2 – What time of the year?
3- what is the possible hight of target?
- Lower tem. with height (lapse rate)

4-How thick is the cloud?
- Ch 7(8.7) can read high BT

5- What is the type of the ground?
- Vegetation has higher Emissivity in Ch2
- Sand has low Emissivity in Ch7 High in Ch10

6- How humid is the atmosphere?
- water vapor absorbed more in Ch7

Weighting functions
Source: EUMETSA

Max. signal in the window channels from the surface and lower part of troposphere

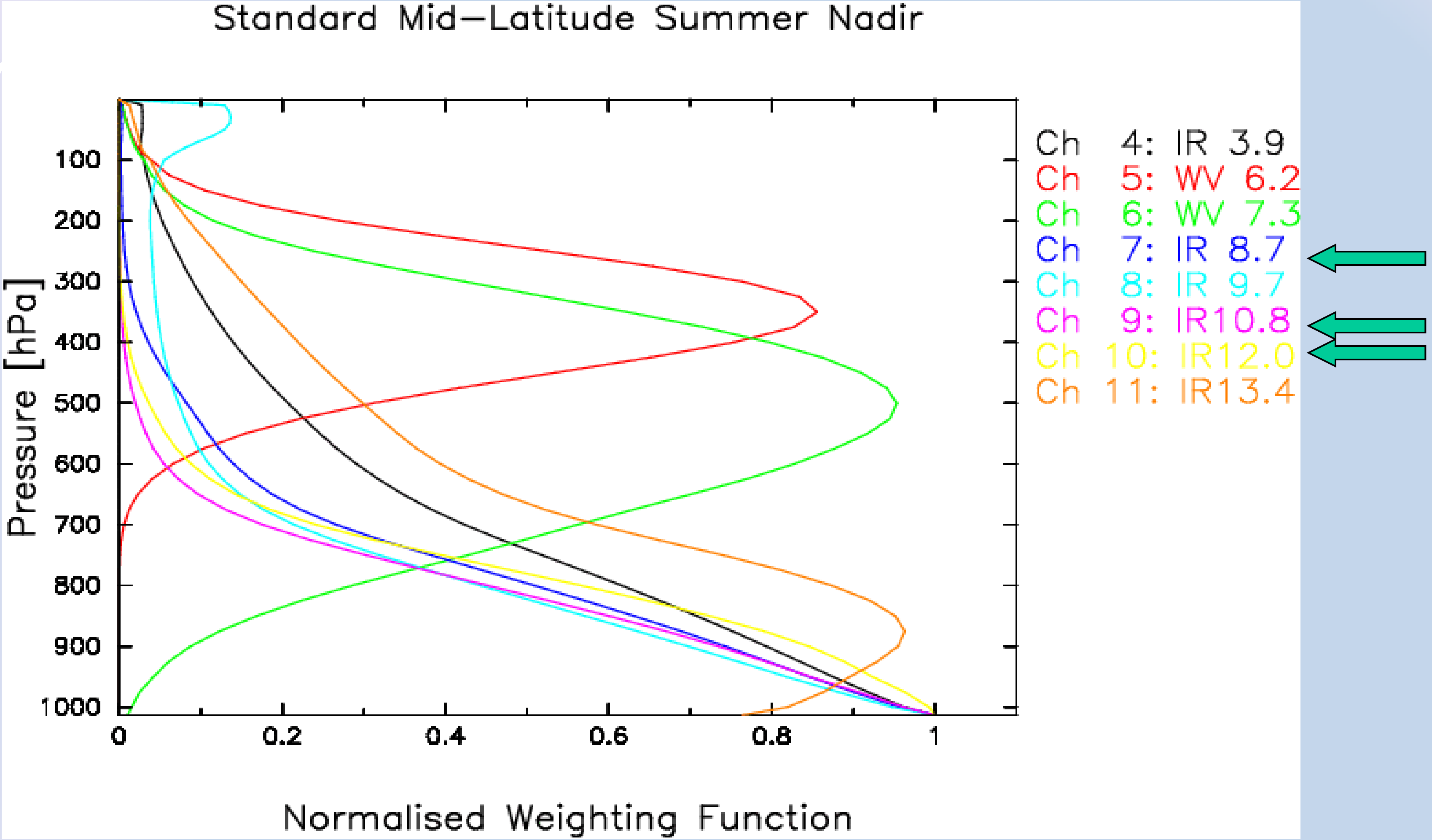
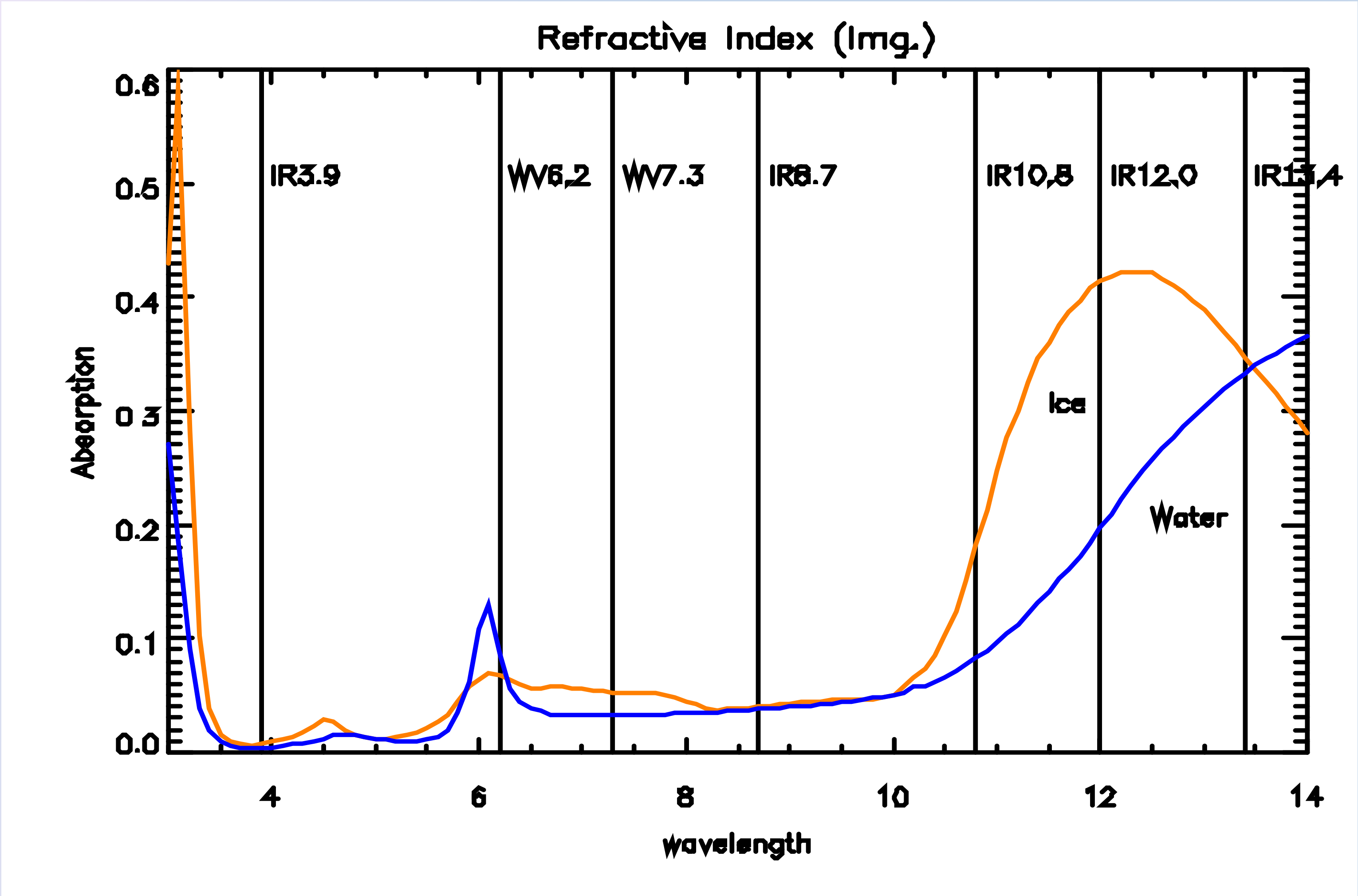


Figure 3c

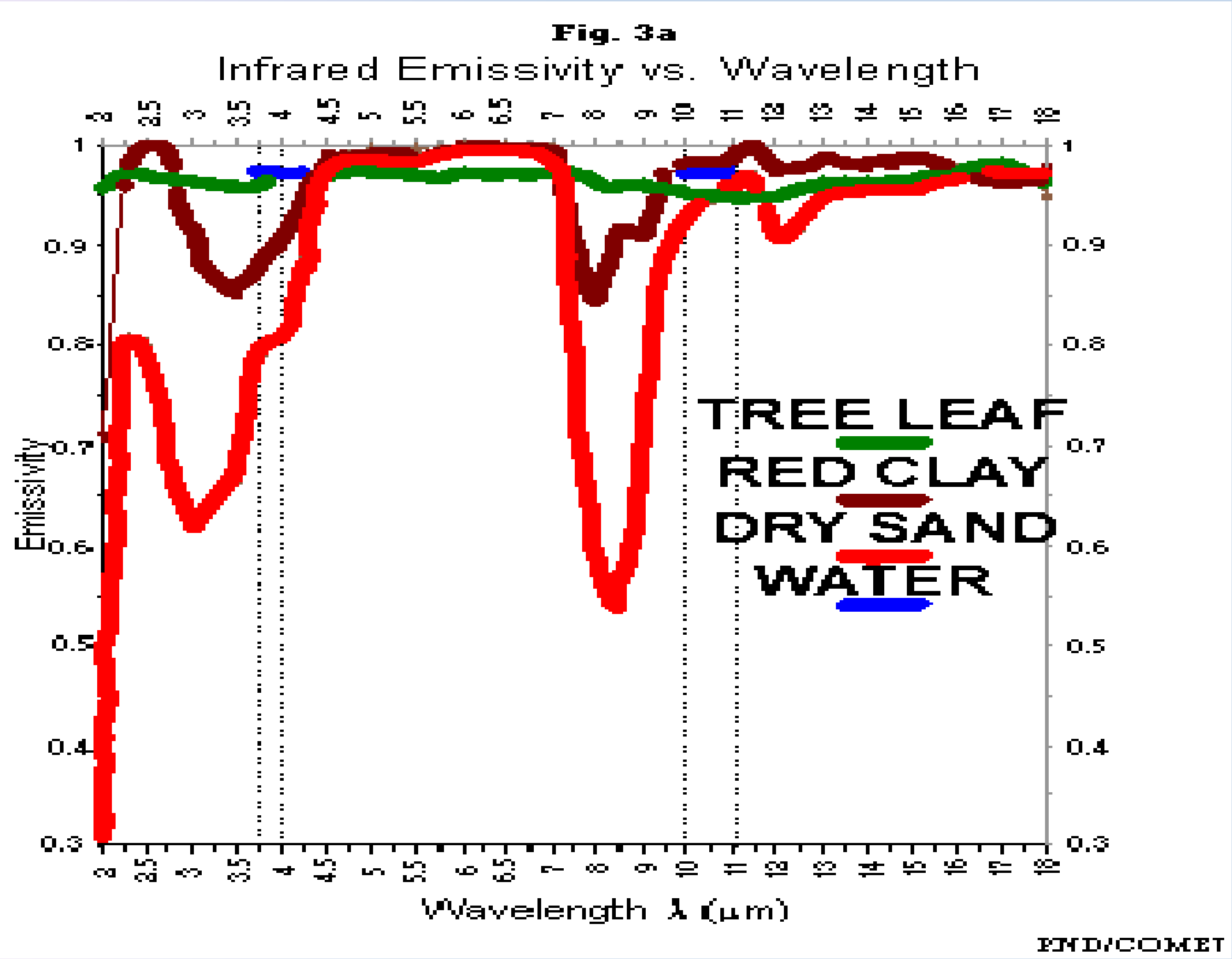
For Thin CLOUDS



* High Thin clouds : Channel8.7 has the highest brightness temp. (BT)

* As the cloud top lowers, the BT of the difference Ch7-Ch9 changes from positive to negative depending on how thick the cloud and how humid the atmosphere in the lower level

Emissivity



IR8.7: sand has much less emissivity than at IR10.8

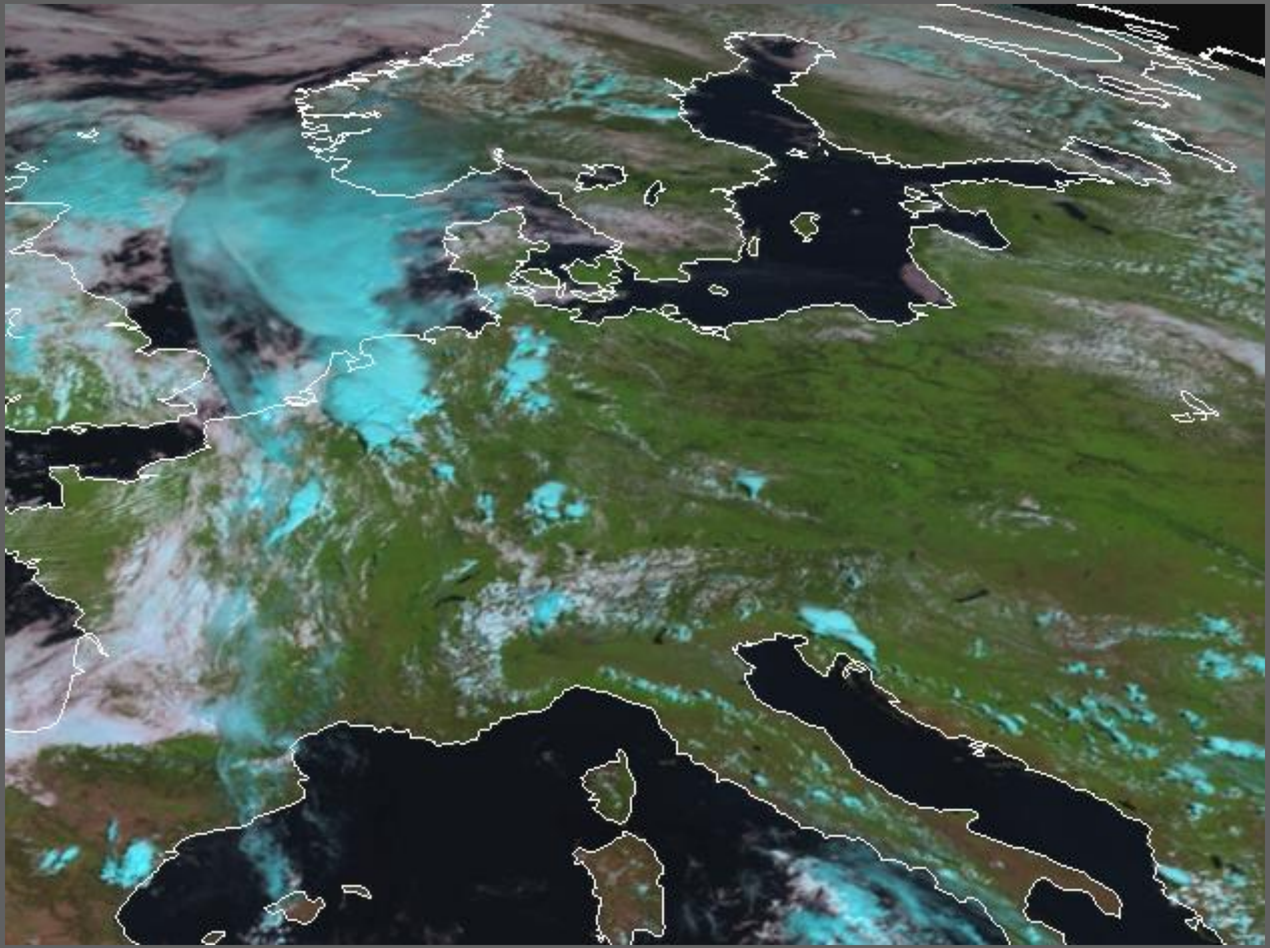
Typical Convective Development
- Daytime -

	VIS0.6/0.8	NIR1.6	IR3.9	IR10.8
I. Very early stage (low, warm water cloud)	white (255) opt thick	white (255) water	white (255) water	light grey (200) warm
II. First convection* (first convective towers)	white (255) opt thick	white (255) supercooled water	white (255) supercooled water	dark grey (100) **cold**
III. First icing (transformation in Cb)	white (255) opt thick	li. grey(200) **small ice**	grey (150) **small ice**	black (0) very cold
IV. Large icing (Cb anvils)	white (255) opt thick	da.Grey(100) **large ice**	black (0) **large ice**	black (0) very cold

Example: RGB 03-02-01

	Red NIR1.6	Green VIS0.8	Blue VIS0.6	RGB-Colour
I. Very early stage	255	255	255	white
II. First convection	255	255	255	white
III. First icing	200	255	255	light cyan
IV. Large icing	100	255	255	dark cyan

Example: RGB 03-02-01



MSG-1, 8 June 2003, 11:00 UTC, RGB 03-02-01

Exercise RGB 01-04-09

Fill in the table & colours as in the previous example

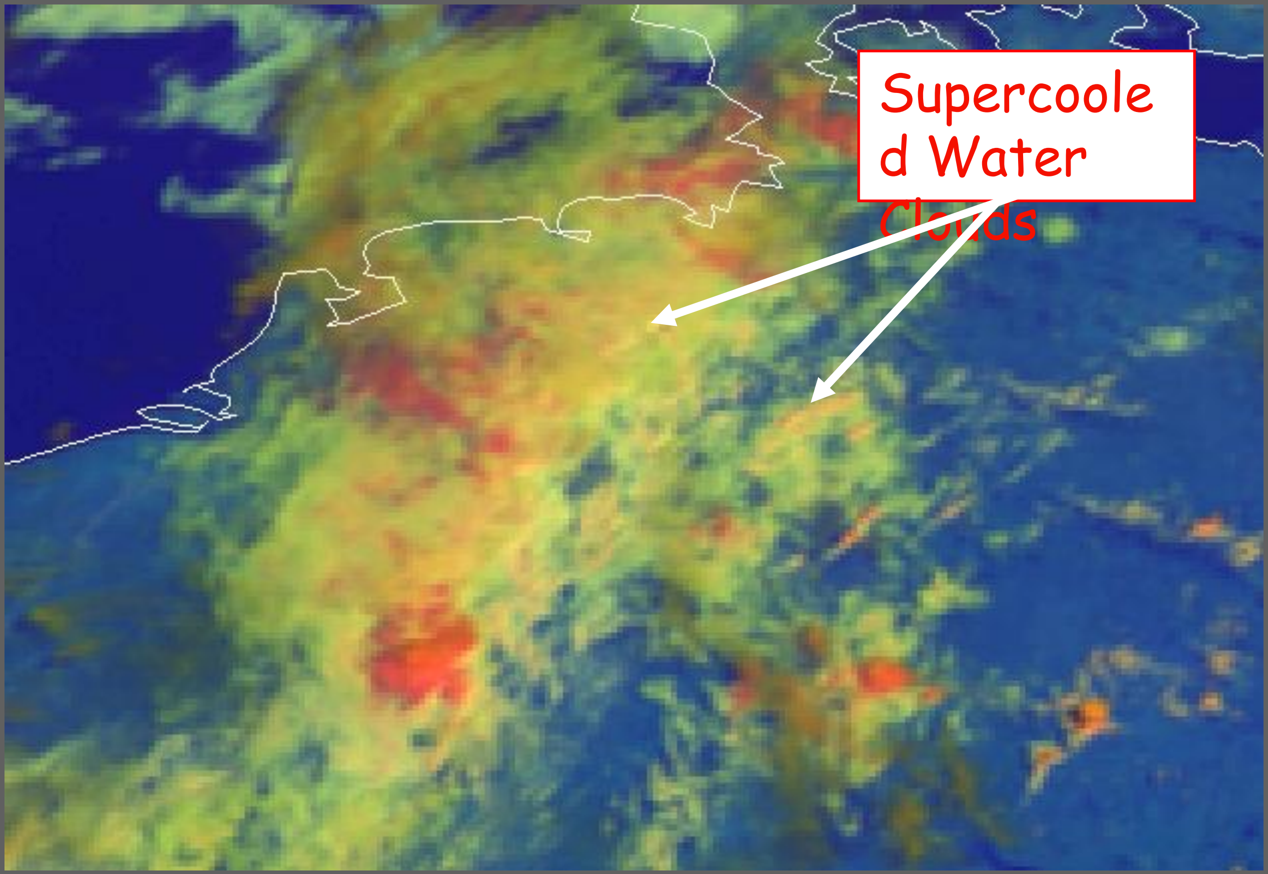
Typical Convective Development

	Red VIS0.6	Green IR3.9	Blue IR10.8	RGB-Colour
I. Very early stage				
II. First convection				
III. First icing				
IV. Large icing				

Solution RGB 01-04-09

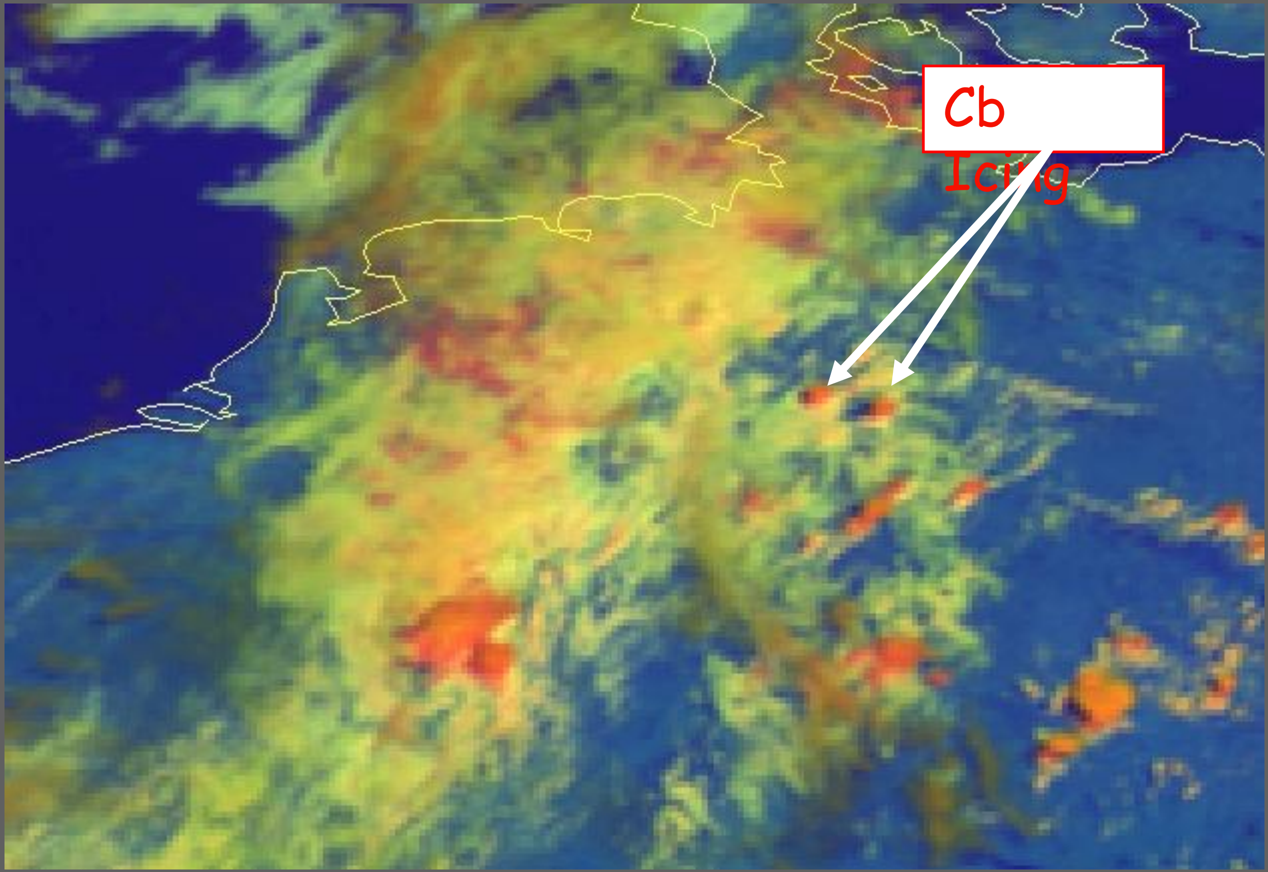
	Red VIS0.6	Green IR3.9	Blue IR10.8	RGB-Colour	
I. Very early stage	255	255	200	white-light yellow	
II. First convection	255	255	100	yellow	
III. First icing	255	150	0	orange	
IV. Large icing	255	0	0	red	

Example Phase II: First Convection (Supercooled Clouds)



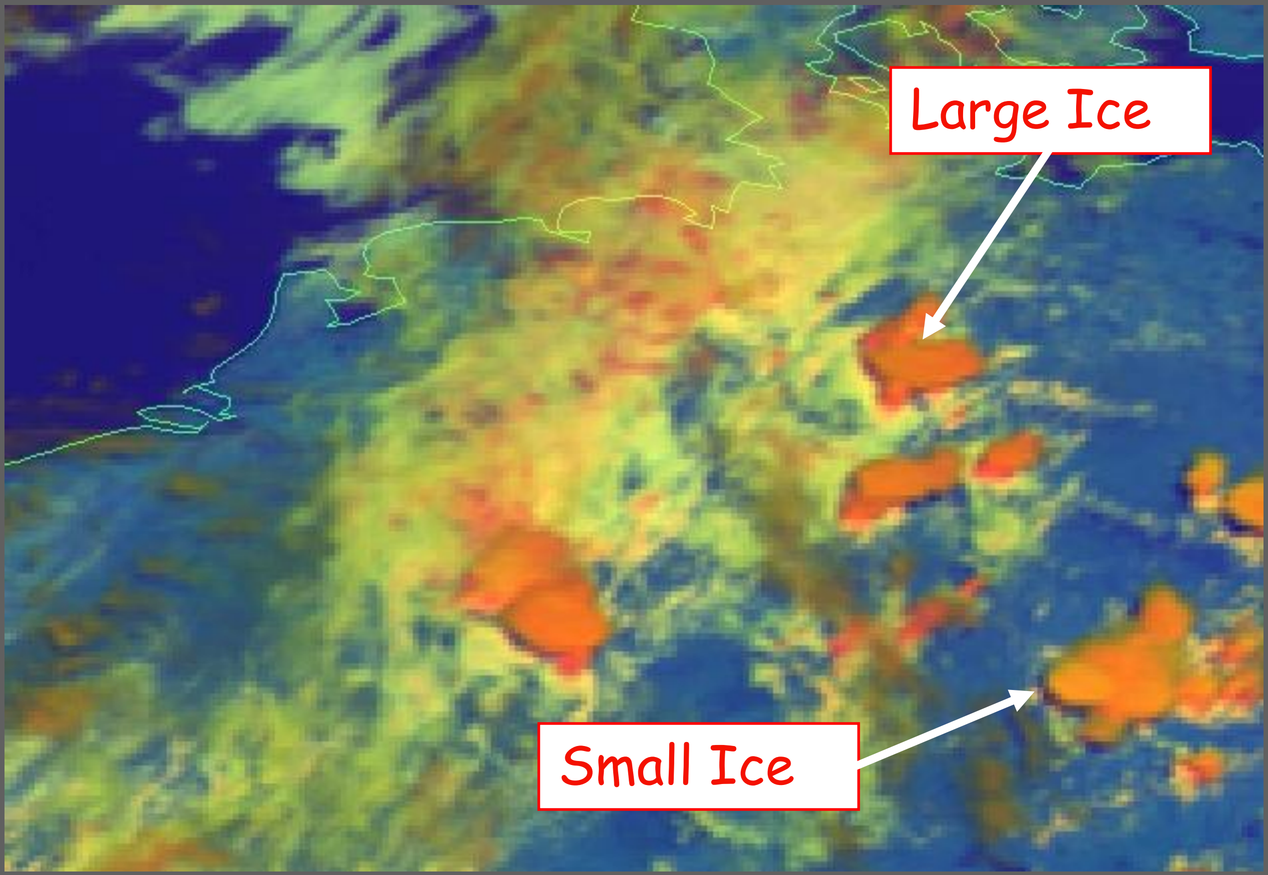
MSG-1, 5 June 2003, 10:00 UTC, RGB 01-03-09

Example Phase III: First Icing



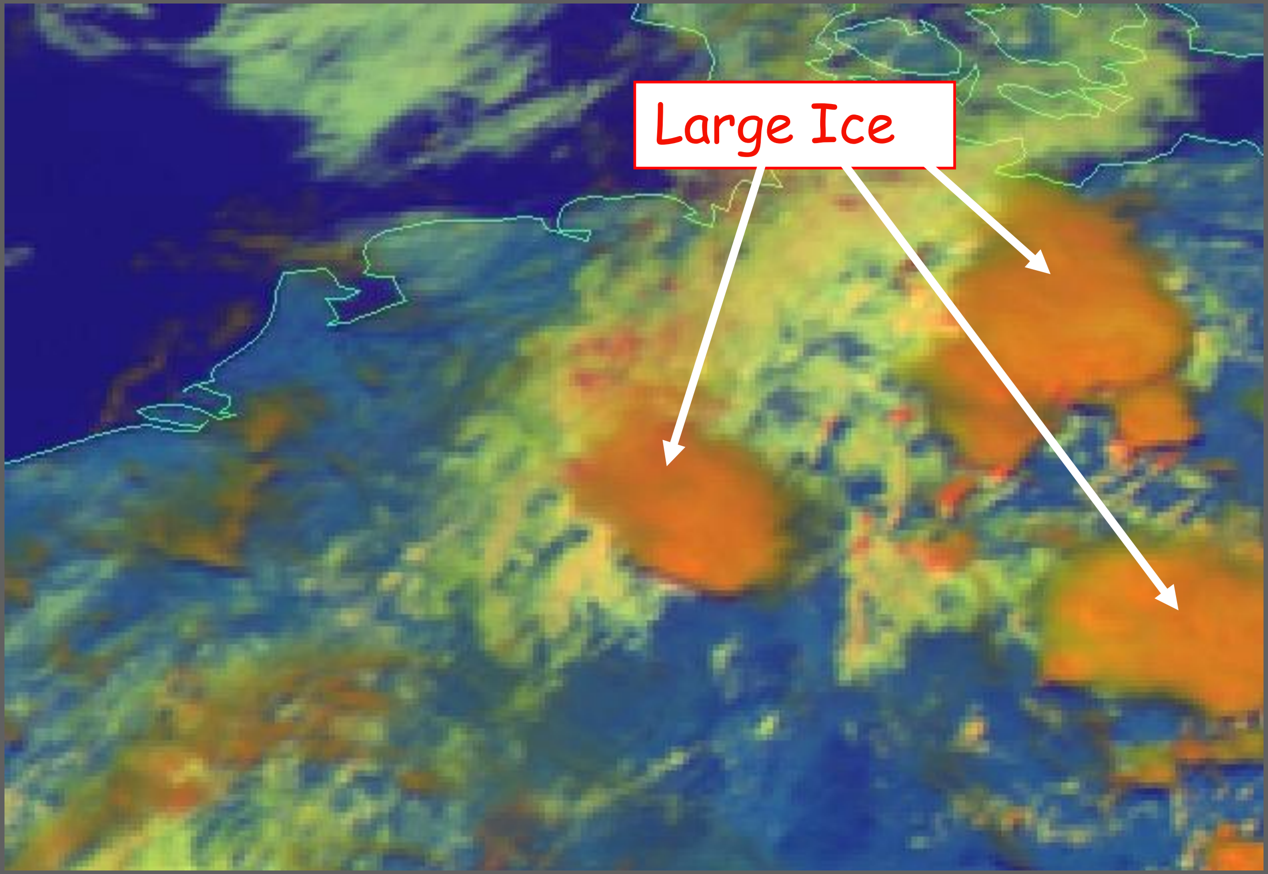
MSG-1, 5 June 2003, 10:30 UTC, RGB 01-03-09

Example Phase IV: Large Icing



MSG-1, 5 June 2003, 11:30 UTC, RGB 01-03-09

Example Phase V: Very Large Icing



MSG-1, 5 June 2003, 13:30 UTC, RGB 01-03-09

Exercise RGB 03-04-09

Fill in the colours as in the previous examples

	Red NIR1.6	Green IR3.9	Blue IR10.8	RGB-Colour
I. Very early stage				
II. First convection				
III. First icing				
IV. Large icing				

Solution RGB 03-04-09

	Red NIR1.6	Green IR3.9	Blue IR10.8	RGB-Colour
I. Very early stage	255	255	200	white-light yellow
II. First convection	255	255	100	yellow
III. First icing	200	150	0	brown
IV. Large icing	100	0	0	dark brown

Exercise RGB 01-03-04

Fill in the colours as in the previous examples

	Red VIS0.6	Green NIR1.6	Blue IR3.9	RGB-Colour
I. Very early stage				
II. First convection				
III. First icing				
IV. Large icing				

Solution RGB 01-03-04

	Red VIS0.6	Green NIR1.6	Blue IR3.9	RGB-Colour
I. Very early stage	255	255	255	white
II. First convection	255	255	255	white
III. First icing	255	200	150	khaki-brown
IV. Large icing	255	100	0	red-orange

Summary

- RGB display is a fast technique for feature enhancement exploiting additive colour scheme.
- RGB require simple manipulation to obtain optimum colouring (choice of P or S mode for IR channels...ect!)