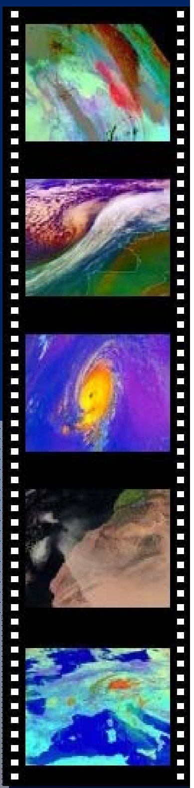
# Introduction to RGB Composited Imagery

Joachim Saalmüller

Jochen Kerkmann



With contributions from:
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# Structure of the presentation

1) Why RGBs?
2) Initial guidance on creating RGBs
3) MSG: main improvements with a multispectral imager
4) RGBs for operational forecasting
5) Meteosat Third Generation (MTG)

# PART 1:

# WHY RGB PRODUCTS ?

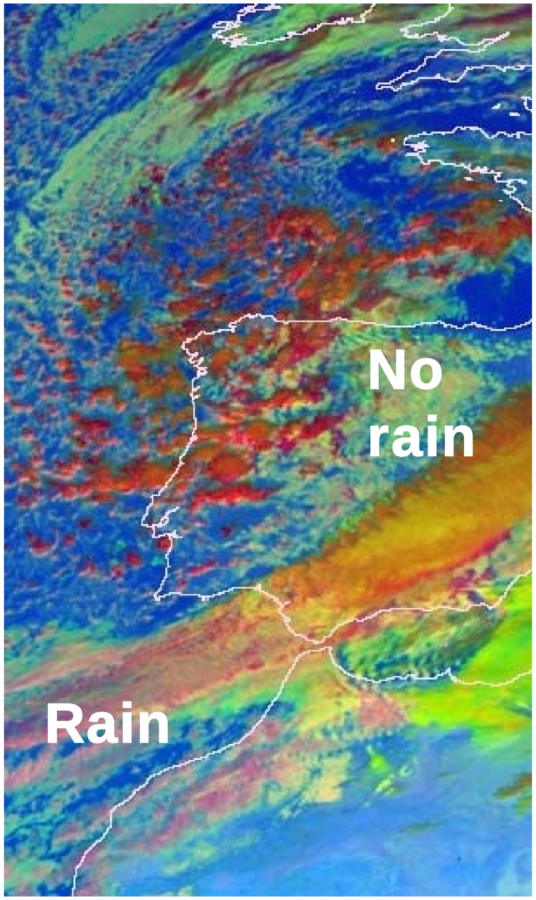
# Why RGB Products?

- With dramatically increasing amount of imager data (MSG, H-8, GOES-R): need to package and consolidate information content into easy to use products

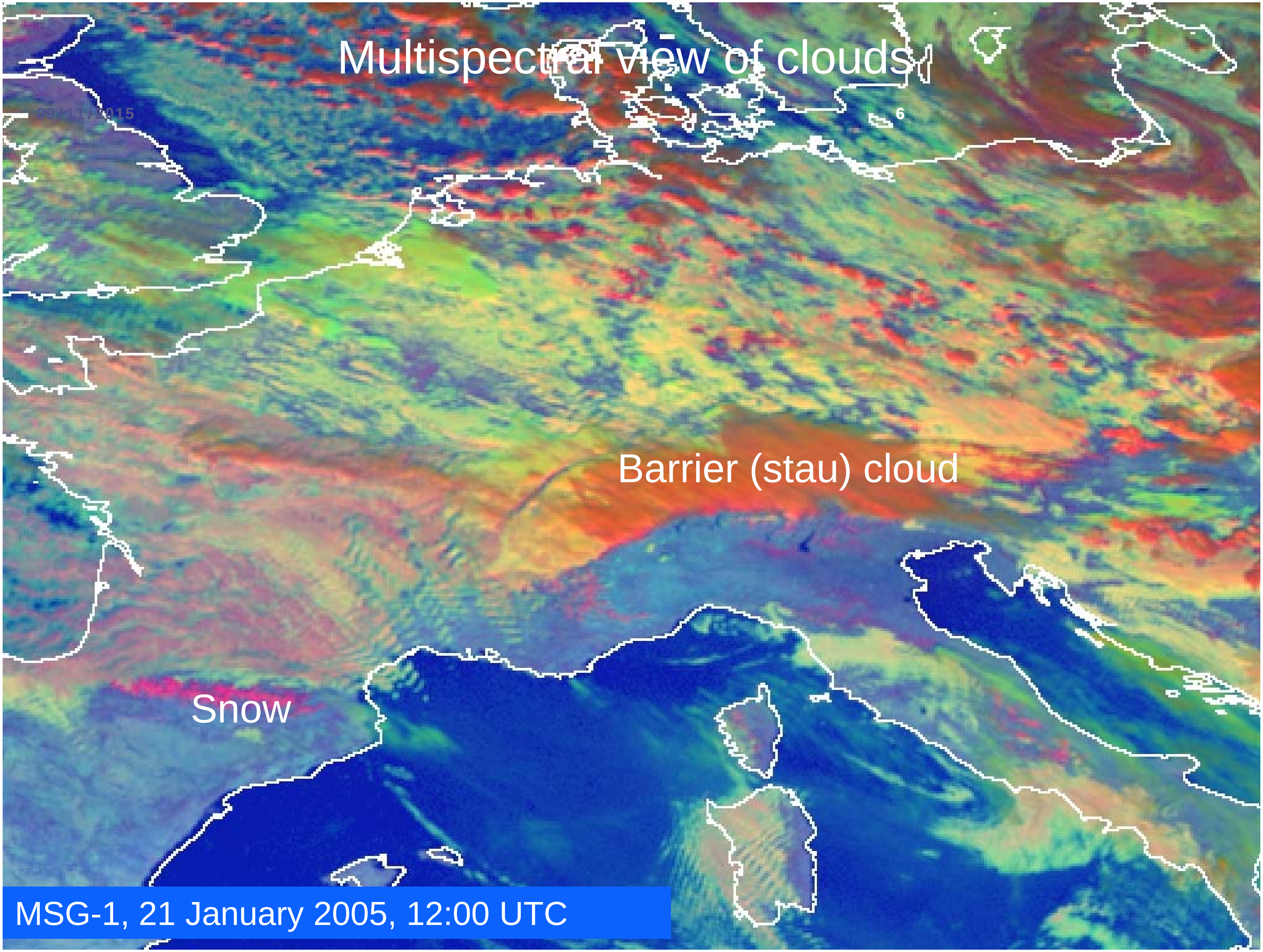
- RGB processing consolidates information from different spectral channels into single products that provide more information than any single image can provide

# Multispectral view of tomatoes & clouds

Play Webcast




Source: Prof. Daniel Rosenfeld


Multispectral view of clouds
Barrier (stau) cloud
Snow
MSG-1, 21 January 2005, 12:00 UTC

# Evolution of RGBs

| | |
|---|---|
| **1990ies:** | **simple RGBs from LEO satellites (e.g. AVHRR)** |
| **2000:** | **True Colour + Natural Colour RGBs from MODIS** |
| **2002:** | **Launch of MSG-1 with 12 channels** |
| **2003-2005:** | **MSG Interpretation Guide** |
| **2007:** | **First WMO workshop on RGBs** |
| **2012:** | **Second WMO workshop on RGBs** |
| **2014 – 2015:** | **Fine-tuning of RGBs for new instruments and for tropical regions** |

# PART 2:

# INITIAL GUIDANCE ON CREATING RGBs

# Contrast as the central feature

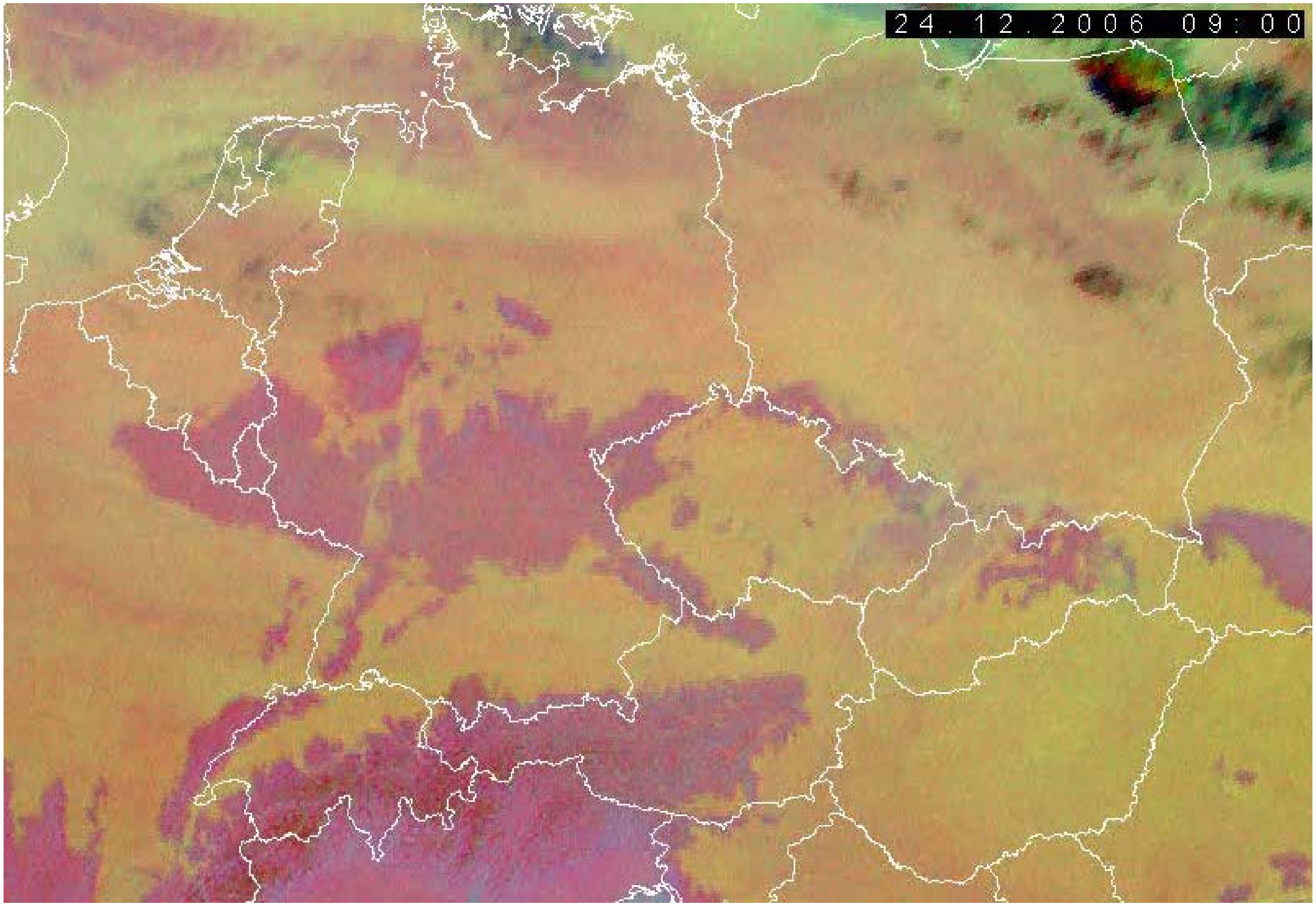
Detection of aerosol, cloud, gas depends on contrast between the ‘target’ and the ‘background’.

Contrast can be:

1. Spectral (e.g. previous examples of dust and cirrus)
2. Texture
3. Time

(Steve Ackerman (Director CIMSS)

# Example: Low Clouds & Power Station Plumes




Source: M. Setvak


**MSG-1, 24-25 December 2006**
**24h- Microphysics RGB**

# RGB Production Process

**Step 1: Determine the purpose of the product**

**Step 2: Select three appropriate channels or channel derivatives that provide useful information for the product**

**Step 3: Pre-process the images as needed to ensure that they provide or emphasize the most useful information**

**Step 4: Assign the three spectral channels or channel derivatives to the three RGB color components**

**Step 5: Review the product for appearance and effectiveness**



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# Selection of the Appropriate Channels

**Select three channels or channel differences that represent three different physical properties !!!**

## MSG Window Channels

| **Channel** | **Main Cloud Physical Properties (clouds, NADIR viewing)** |
|---|---|
| 01 (VIS 0.6) | optical thickness, amount of cloud water and ice |
| 02 (VIS 0.8) | optical thickness, amount of cloud water and ice |
| 03 (NIR 1.6) | optical thickness, particle size & shape, phase |
| 04 (MIR 3.9) | Day-time: top temperature, particle size & shape, phase<br>Night-time: top temperature (very noisy below -50°C) |
| 07 (IR 8.7) | top temperature |
| 09 (IR 10.8) | top temperature |
| 10 (IR 12.0) | top temperature |



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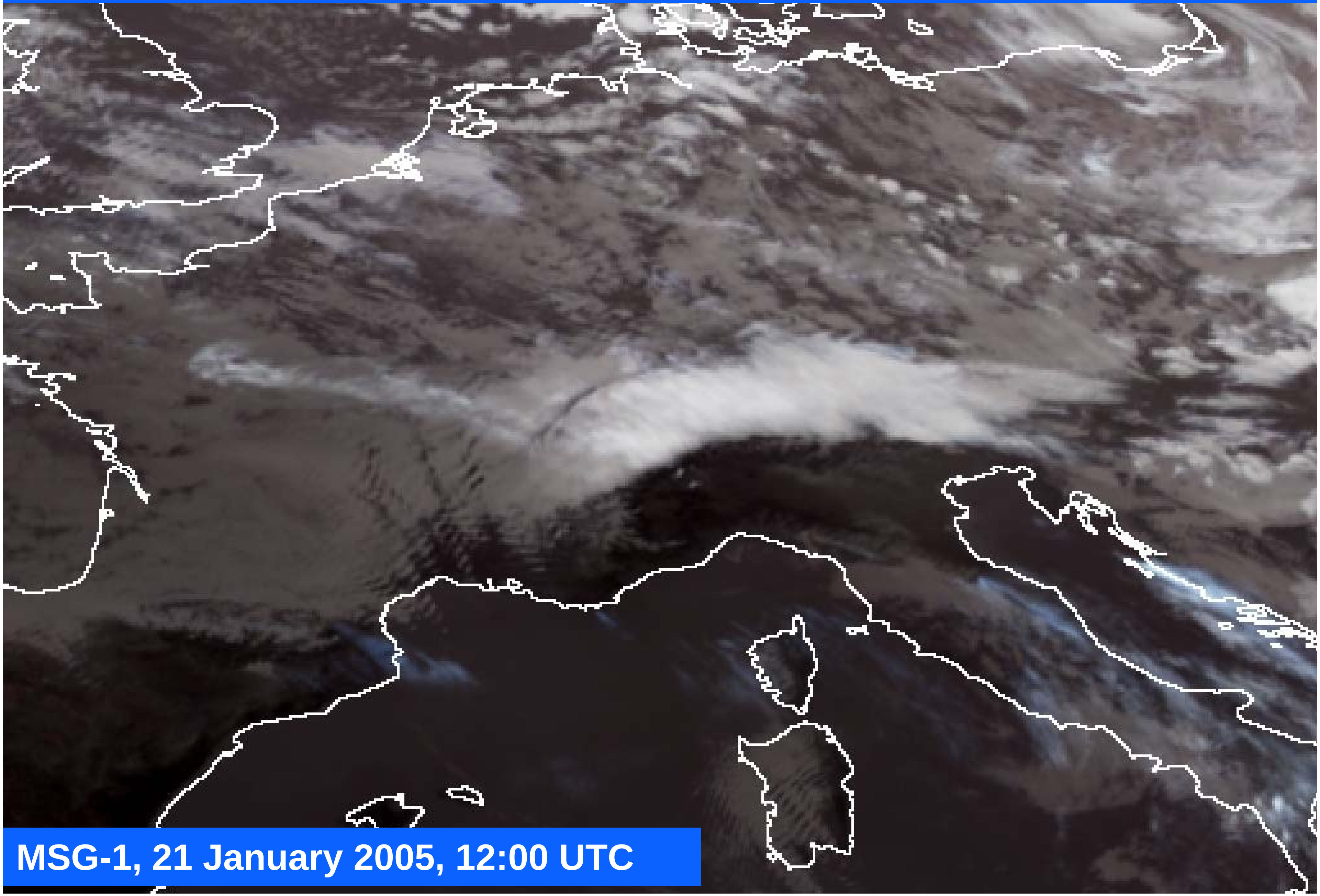
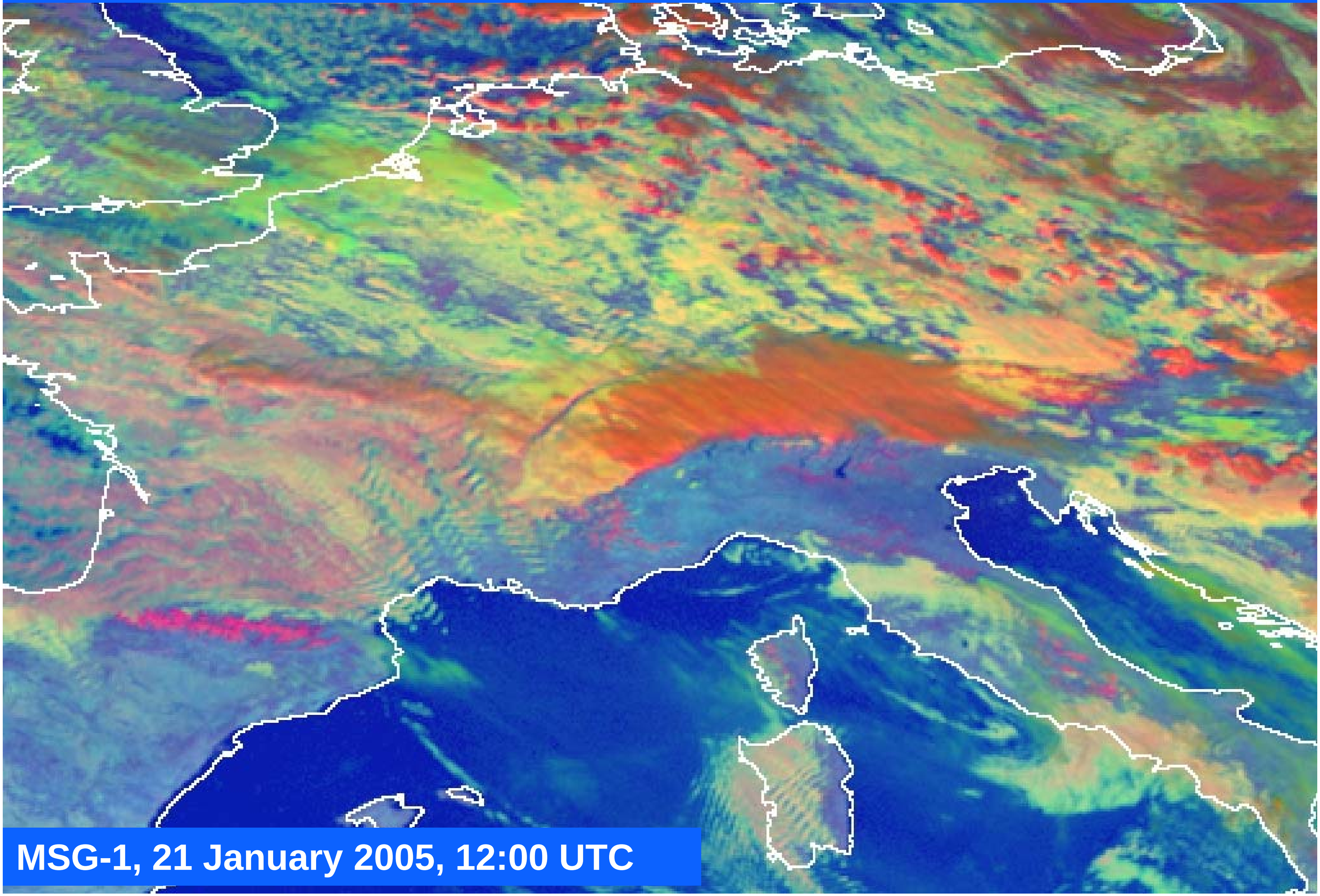
# Not Recommended RGB IR8.7, IR10.8, IR12.0



MSG-1, 21 January 2005, 12:00 UTC

## Recommended RGB VIS0.8, IR3.9, IR10.8

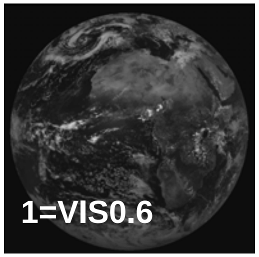


# PART 3:

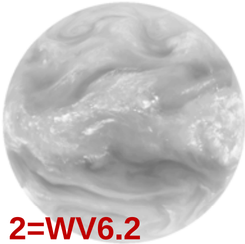
# MAIN IMPROVEMENTS WITH A MULTISPECTRAL IMAGER

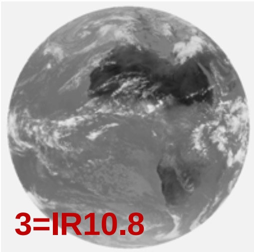
# From First to Second Generation Meteosat

# Meteosat First Generation (MFG)



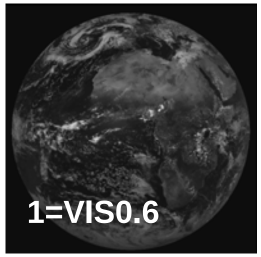

**Solar**
**2.5 km**

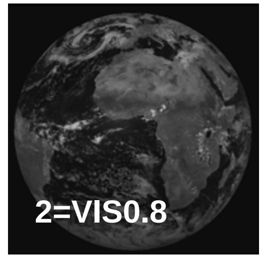


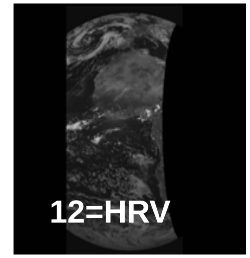




**Thermal**
**5.0 km**

# Meteosat Second Generation (MSG)

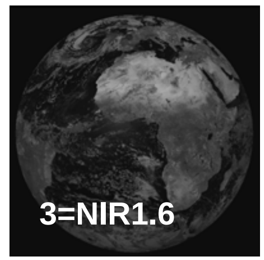


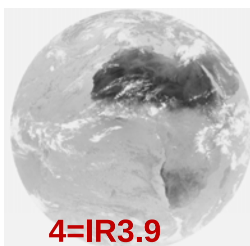



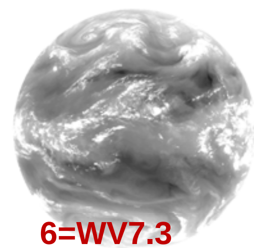

1.0 km

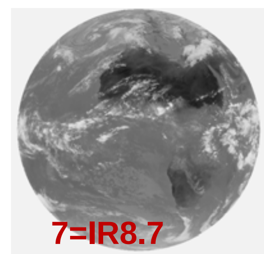
Solar
3.0 km



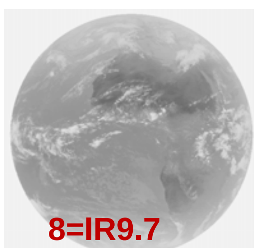



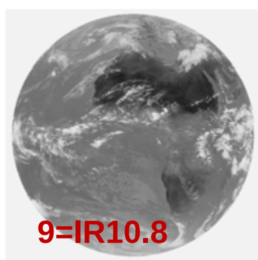


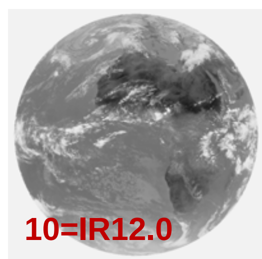


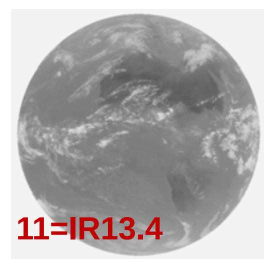




Thermal
3.0 km



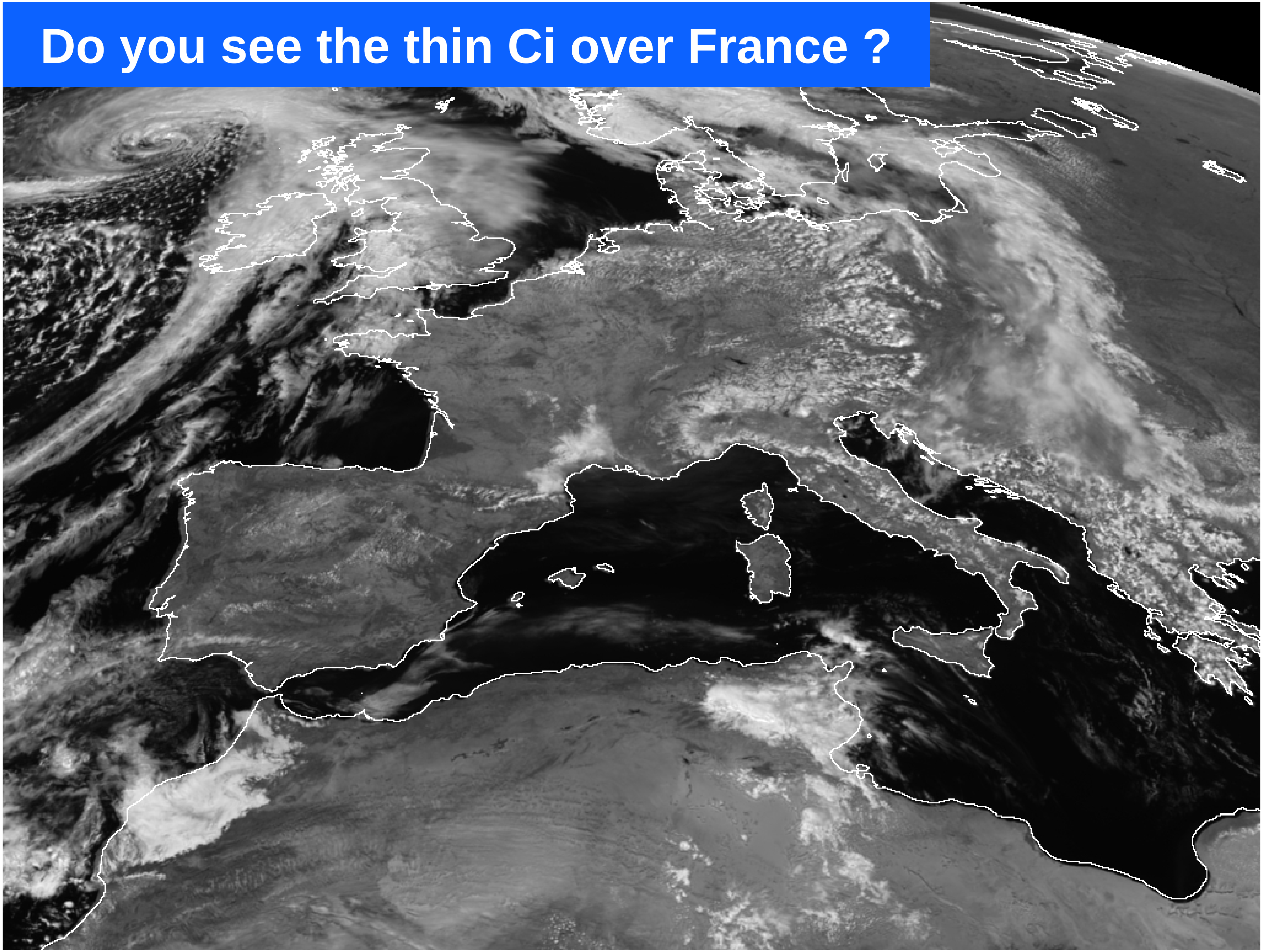



# Main Improvements with MSG

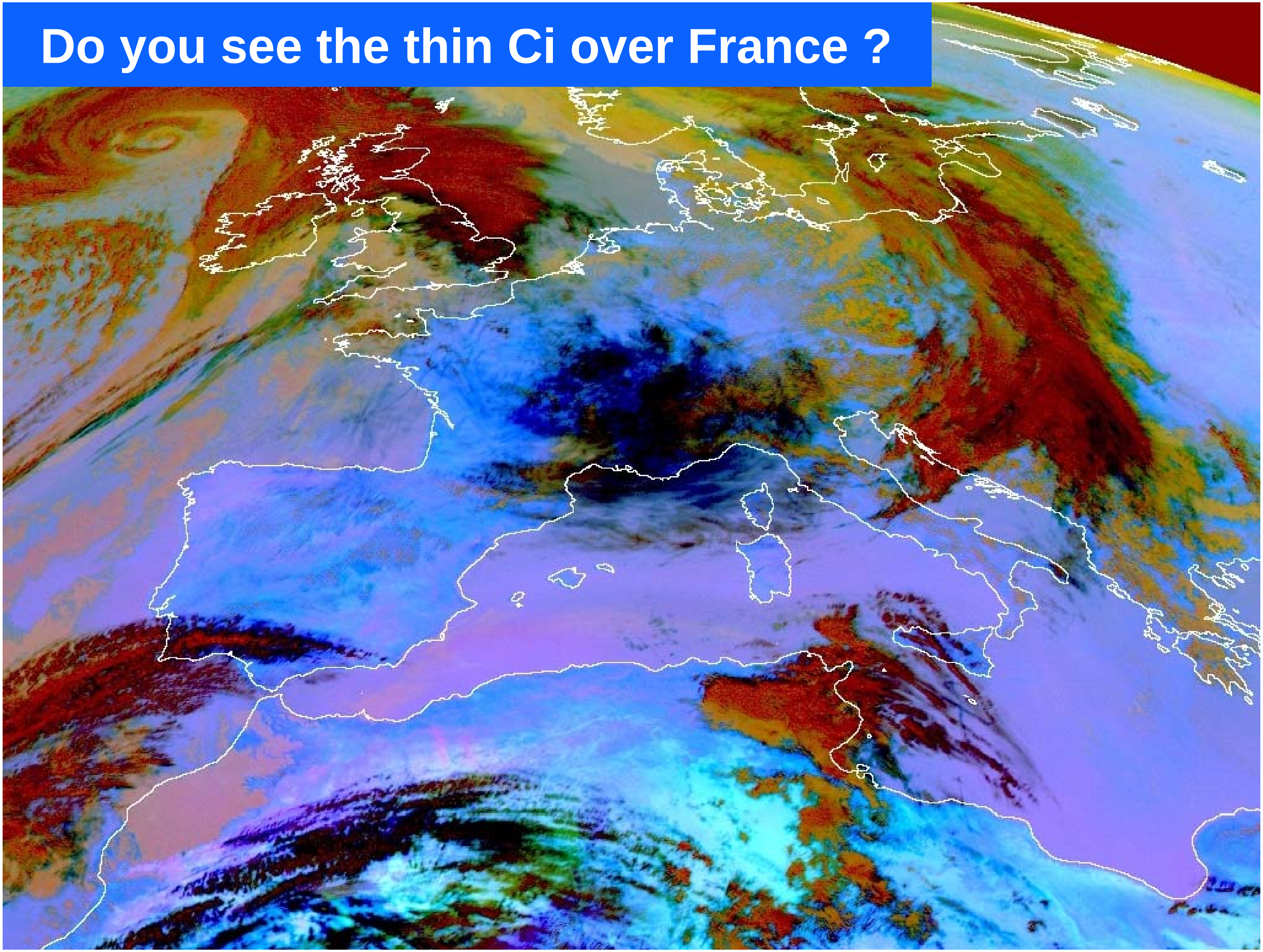
1. Day & **<u>Night</u>** Detection of Low Clouds
2. Cloud properties (phase, particle size, thickness)
3. Dust and Ash detection
4. Instability and moisture estimation
5. Vegetation monitoring
6. Fire detection
7. ...

Examples on the next slides ...

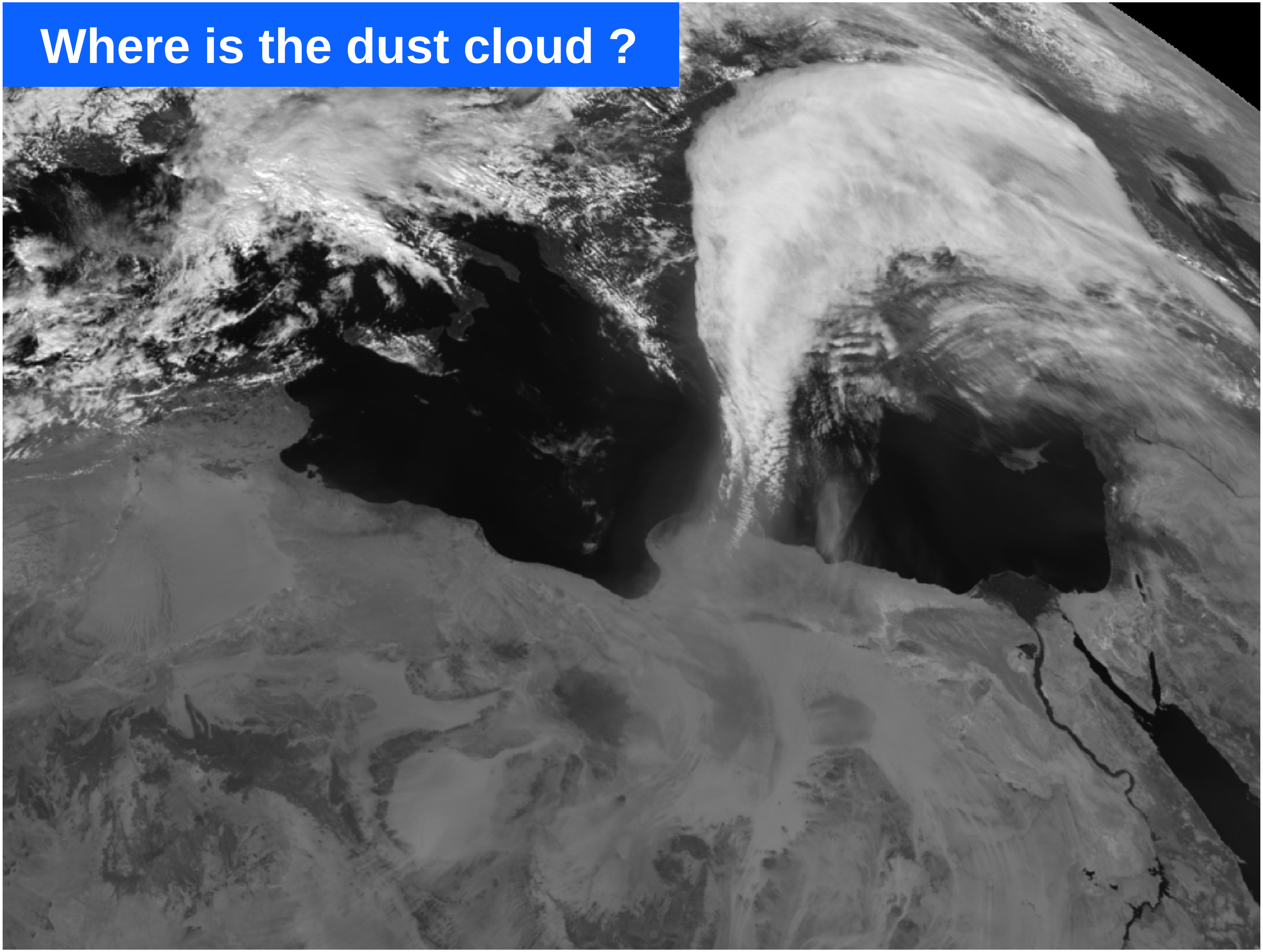
# Do you see the thin Ci over France ?



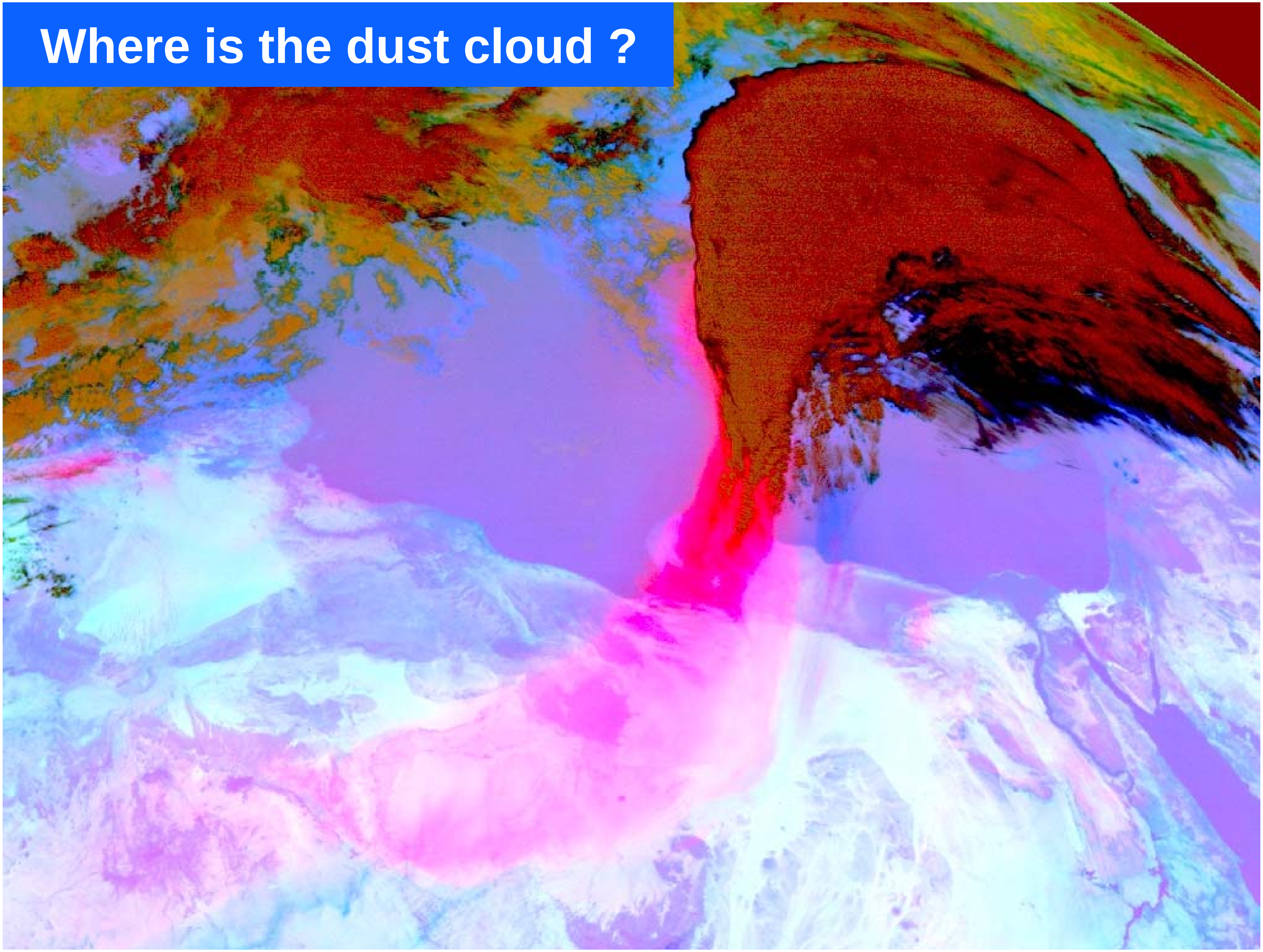
# Do you see the thin Ci over France ?



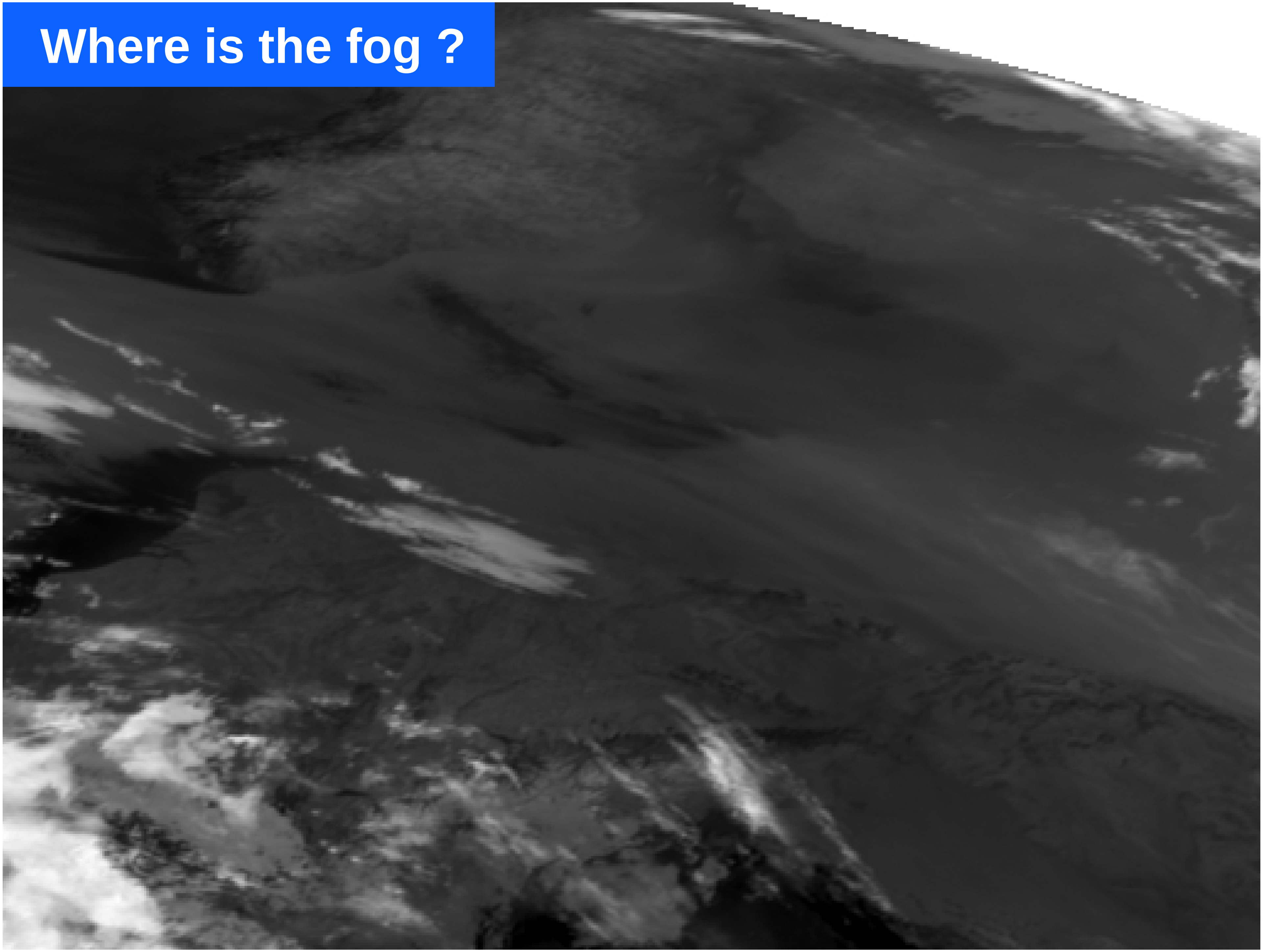
# Where is the dust cloud ?



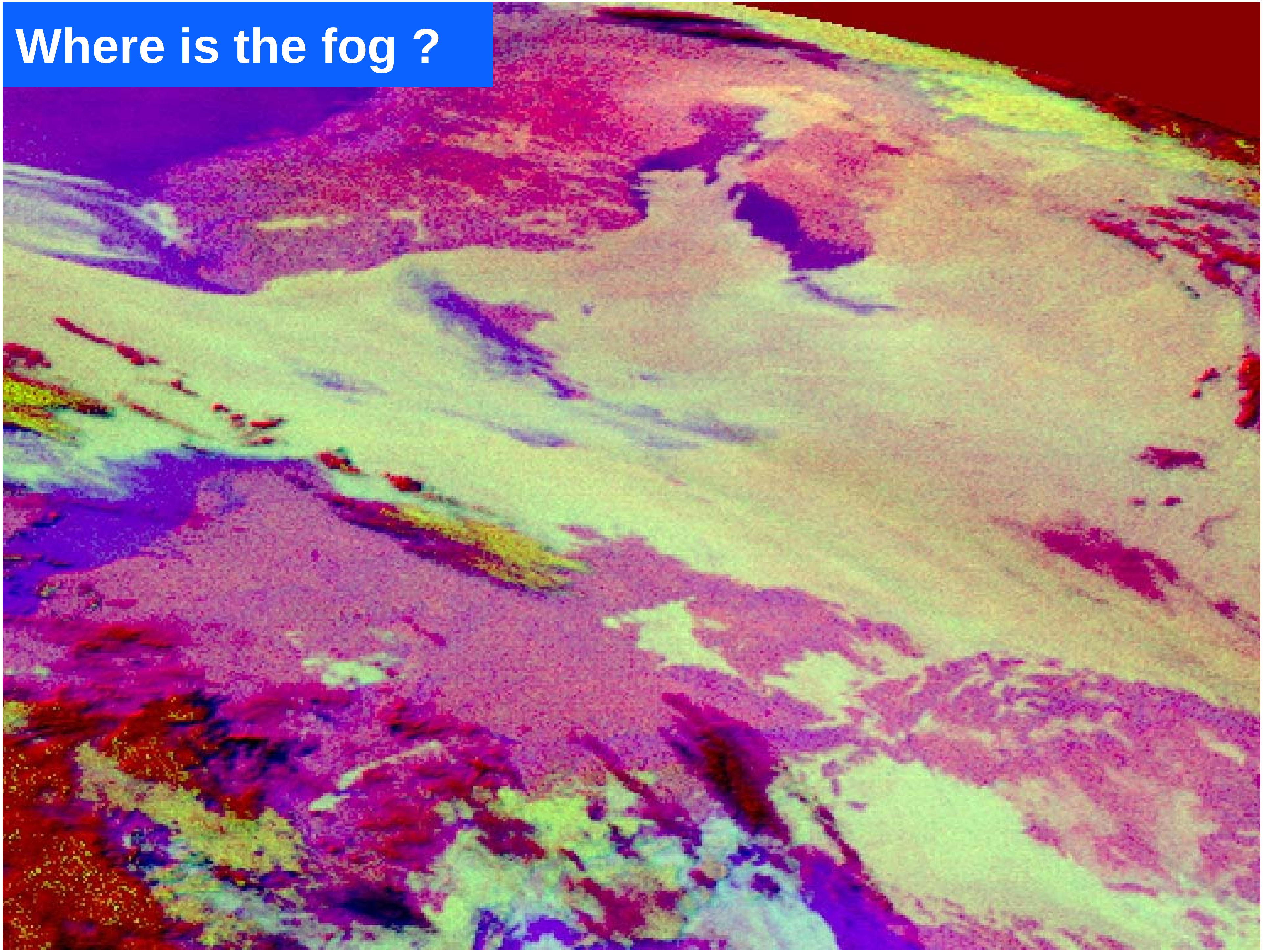
# Where is the dust cloud ?



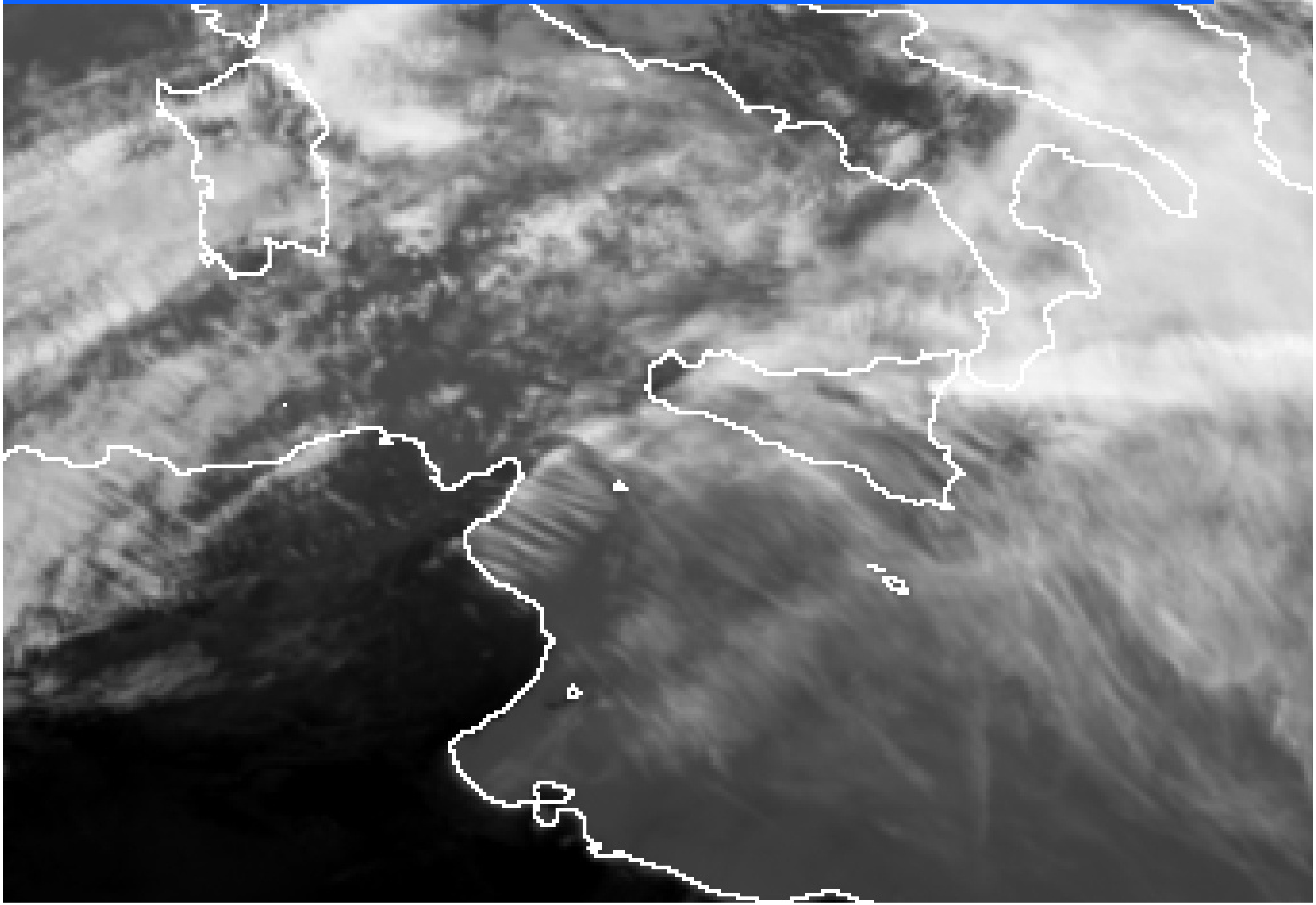
## Where is the fog ?



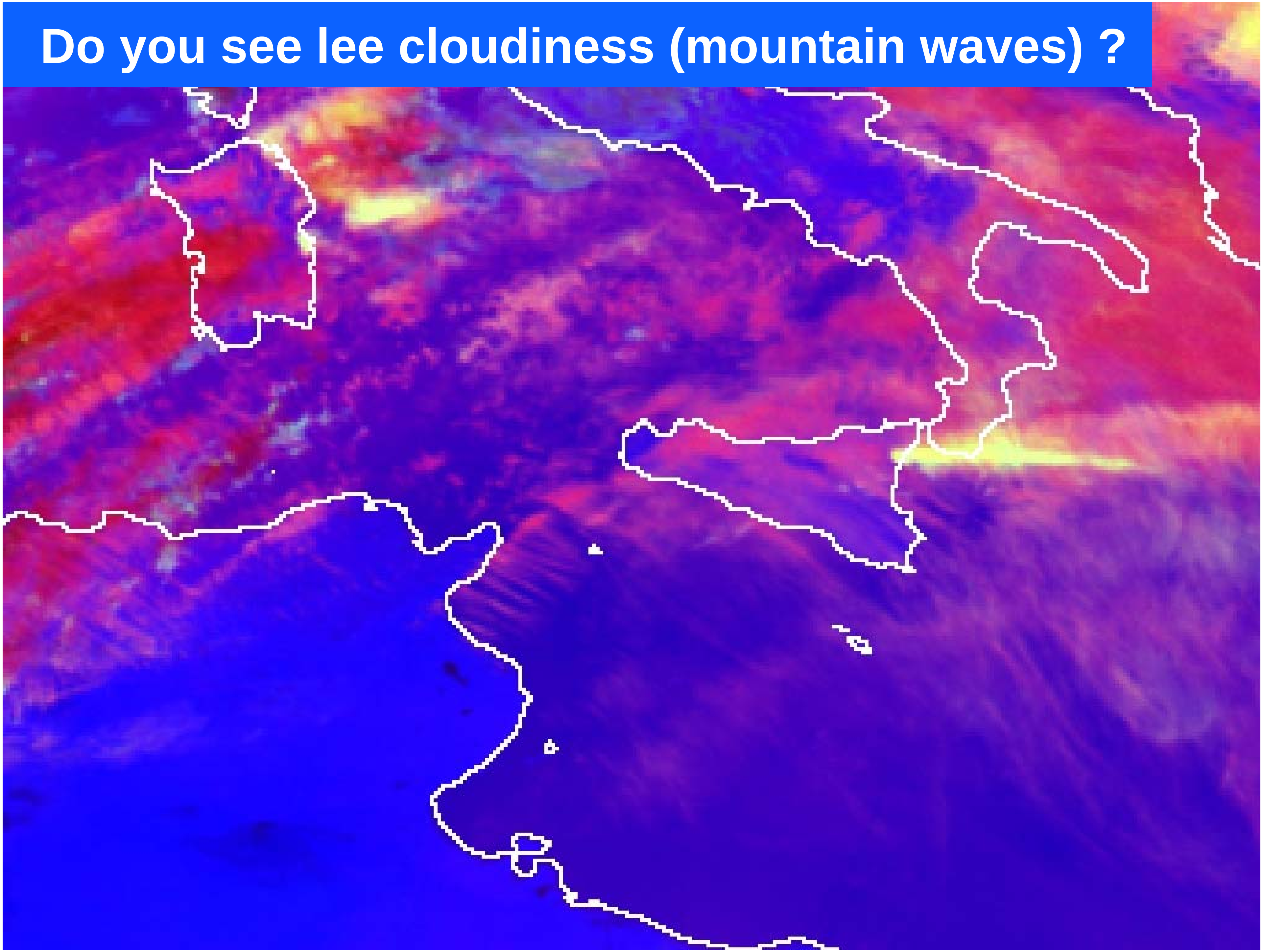
# Where is the fog ?



# Do you see lee cloudiness (mountain waves) ?



# Do you see lee cloudiness (mountain waves) ?



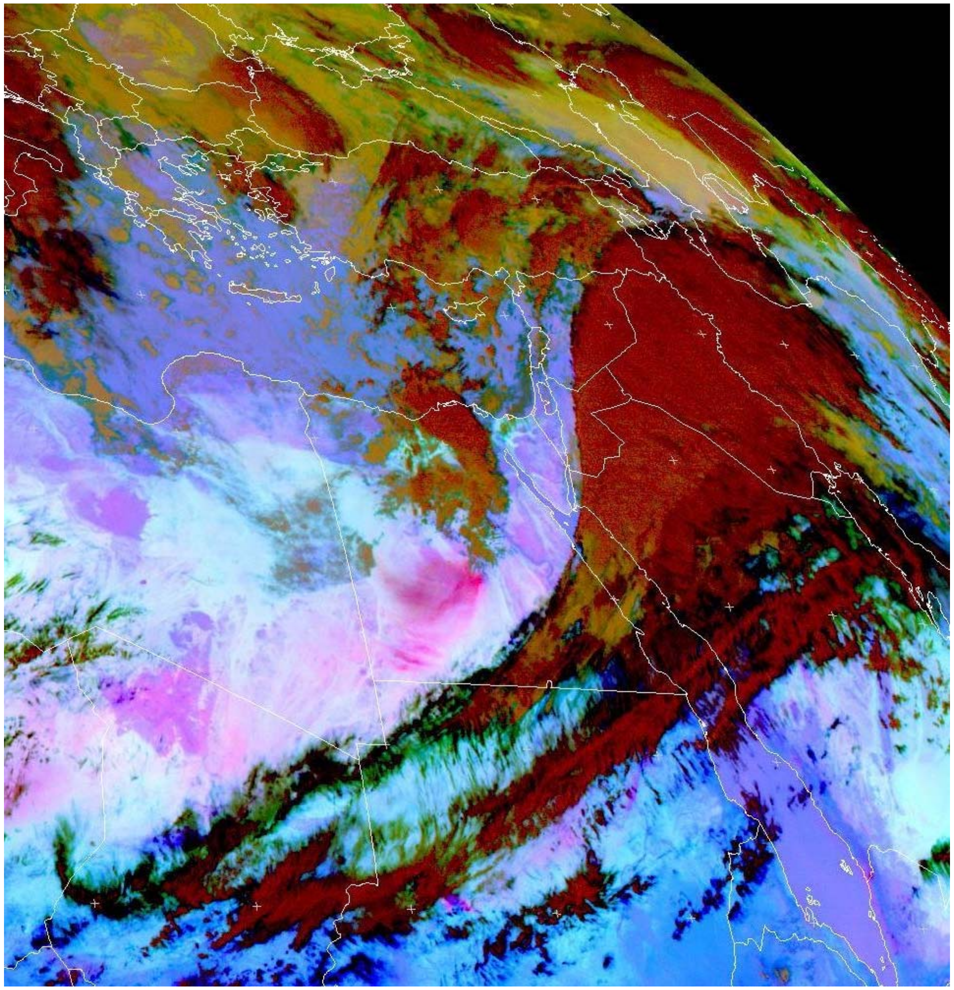
# PART 4:

# RGB PRODUCTS FOR OPERATIONAL FORECASTING

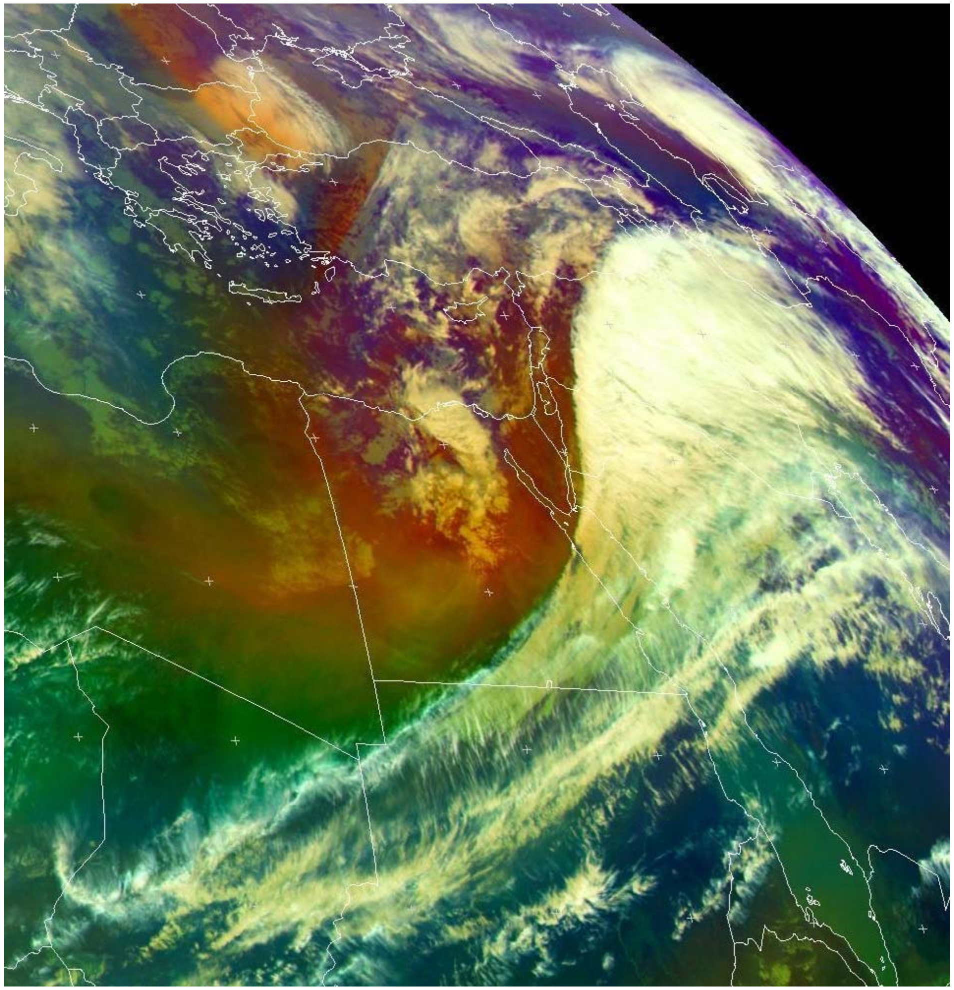
# RGB Products and Applications

| | RGB Composite | Applications | Time |
|---|---|---|---|
| **1.** | RGB 24-h Micro | Dust, Clouds (thickness, phase), Fog, Ash, SO2, Low-level Humidity | Day & Night |
| **2.** | RGB Airmass | Severe Cyclones, Jets, Potential Vorticity Analysis | Day & Night |
| **3a.** | RGB Night Micro | Clouds, Fog, Contrails, Fires | Night |
| **3b.** | RGB Day Micro | Clouds, Convection, Snow, Fog, Fires | Day |
| **4.** | RGB Convection | Severe Convection | Day |
| **5.** | RGB Snow-Fog | Snow, Fog | Day |
| **6.** | RGB Natural Colour | Vegetation, Snow, Smoke, Dust, Fog | Day |

# Most important RGBs (for Operational Forecasting)



**24-h Microphysics (Dust) RGB**



**Airmass RGB**

**28 January 2013, 12:00 UTC**

# 1. RGB 24-hour Microphysics

**R = Difference IR12.0 - IR10.8**
*** Optical Thickness, Tsurf-Tcloud**

**G = Difference IR10.8 - IR8.7**
*** Optical Thickness, Phase, Tsurf-Tcloud**

**B = Channel IR10.8**
*** Top Temperature**

*** Physical Interpretation (for dust/ash/water/ice clouds)**

# 1. RGB 24-hour Microphysics

| | |
|---|---|
| **Applications:** | Clouds, Contrails, Dust, Ash, $SO_2$, Low-level Humidity |
| **Area:** | Full MSG Viewing Area (limb cooling) |
| **Time:** | Day and Night |
| **Users:** | most European & African NMSs, Middle East |

# 1a. 24-hour Cloud Microphysics

devised by: Z. Charvat, HP. Roesli, J. Kerkmann, A. Eronn

**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 |

# 1b. 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 |



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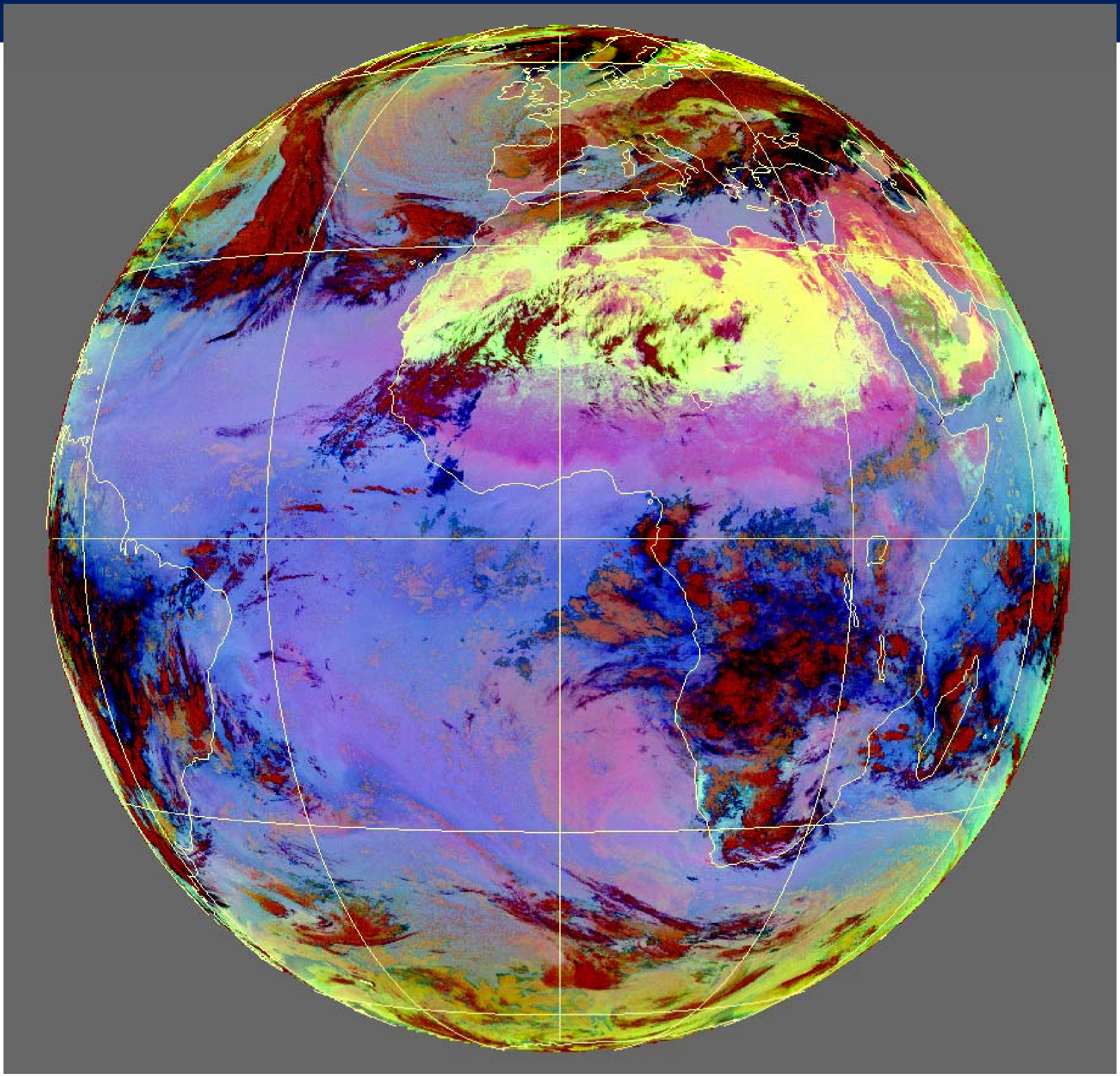
# 1c. 24-hour Ash Microphysics

devised by: J. Kerkmann

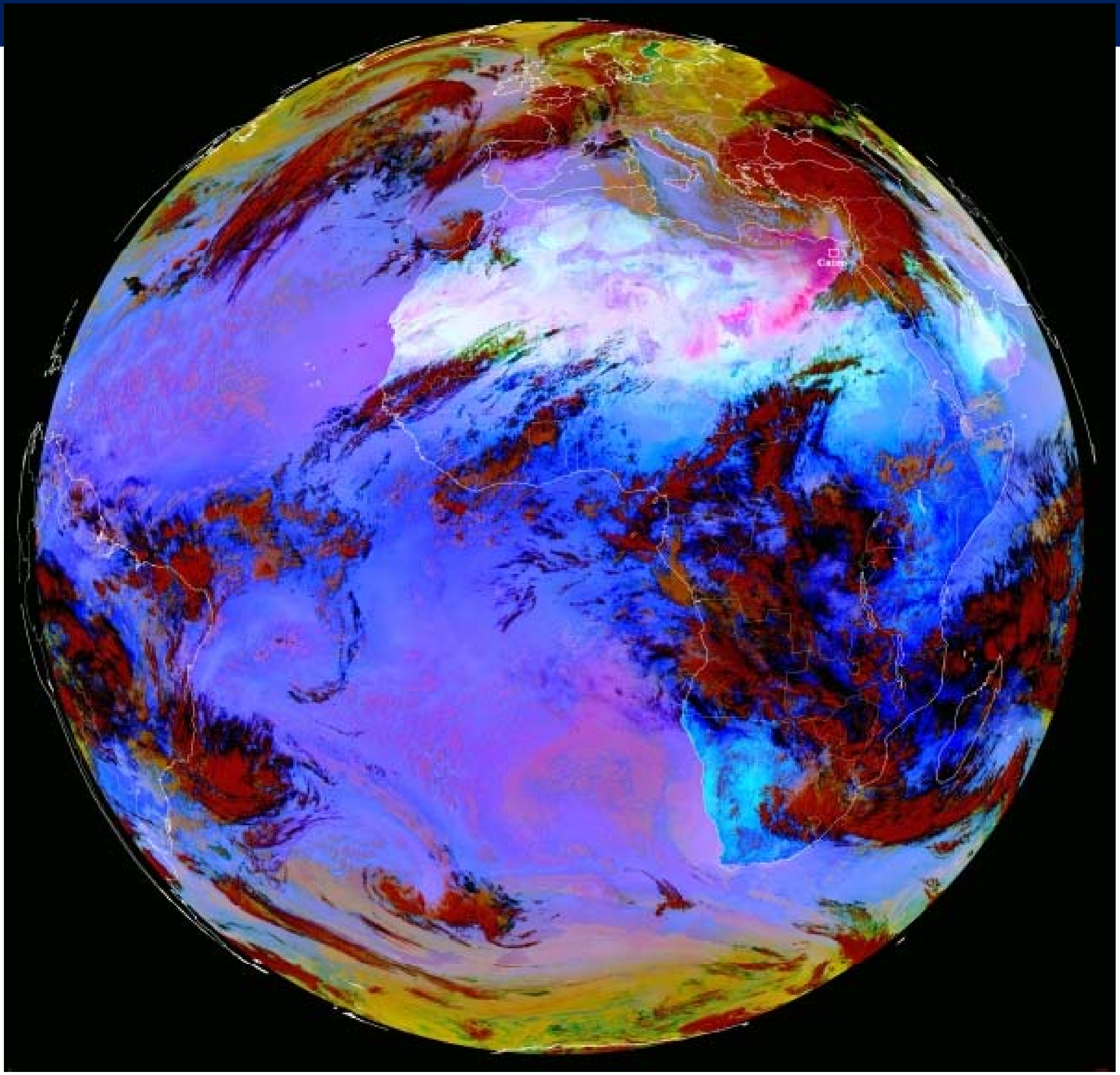
## Recommended Range and Enhancement:

| Beam | Channel | Range | Gamma |
|---|---|---|---|
| Red | IR12.0 - IR10.8 | -4 … +2 K | 1.0 |
| Green | IR10.8 - IR8.7 | -4 … +5 K | 1.0 |
| Blue | IR10.8 | +243 … +303 K | 1.0 |



**RGB**
**24-hour**
**Cloud**
**Microphysics**
**Global View**

**MSG-1**
**25 January 2007**
**04:00 UTC**



**RGB**
**24-hour**
**Dust**
**Microphysics**
**Global View**

**MSG-1**
**22 January 2004**
**12:00 UTC**



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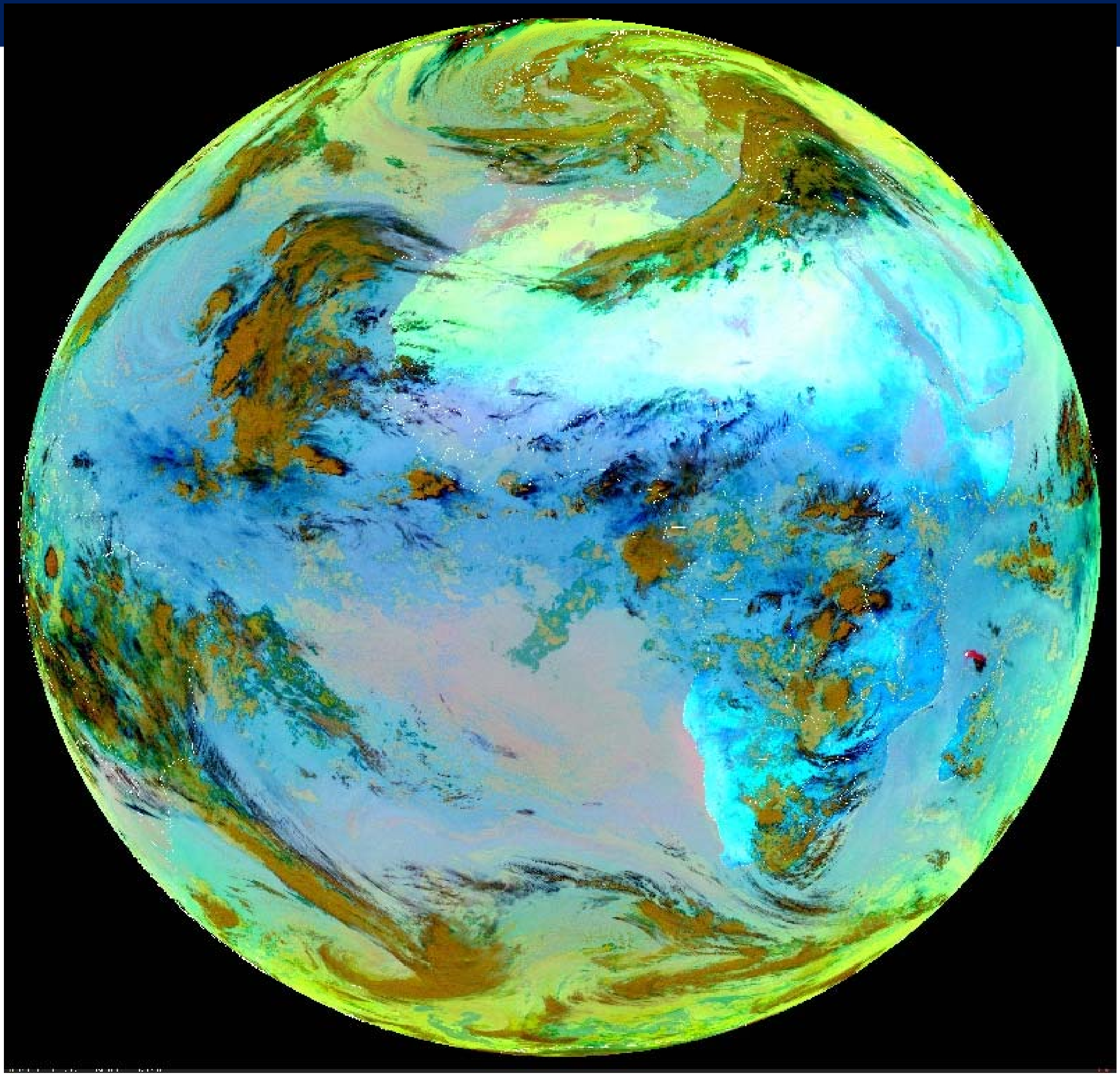
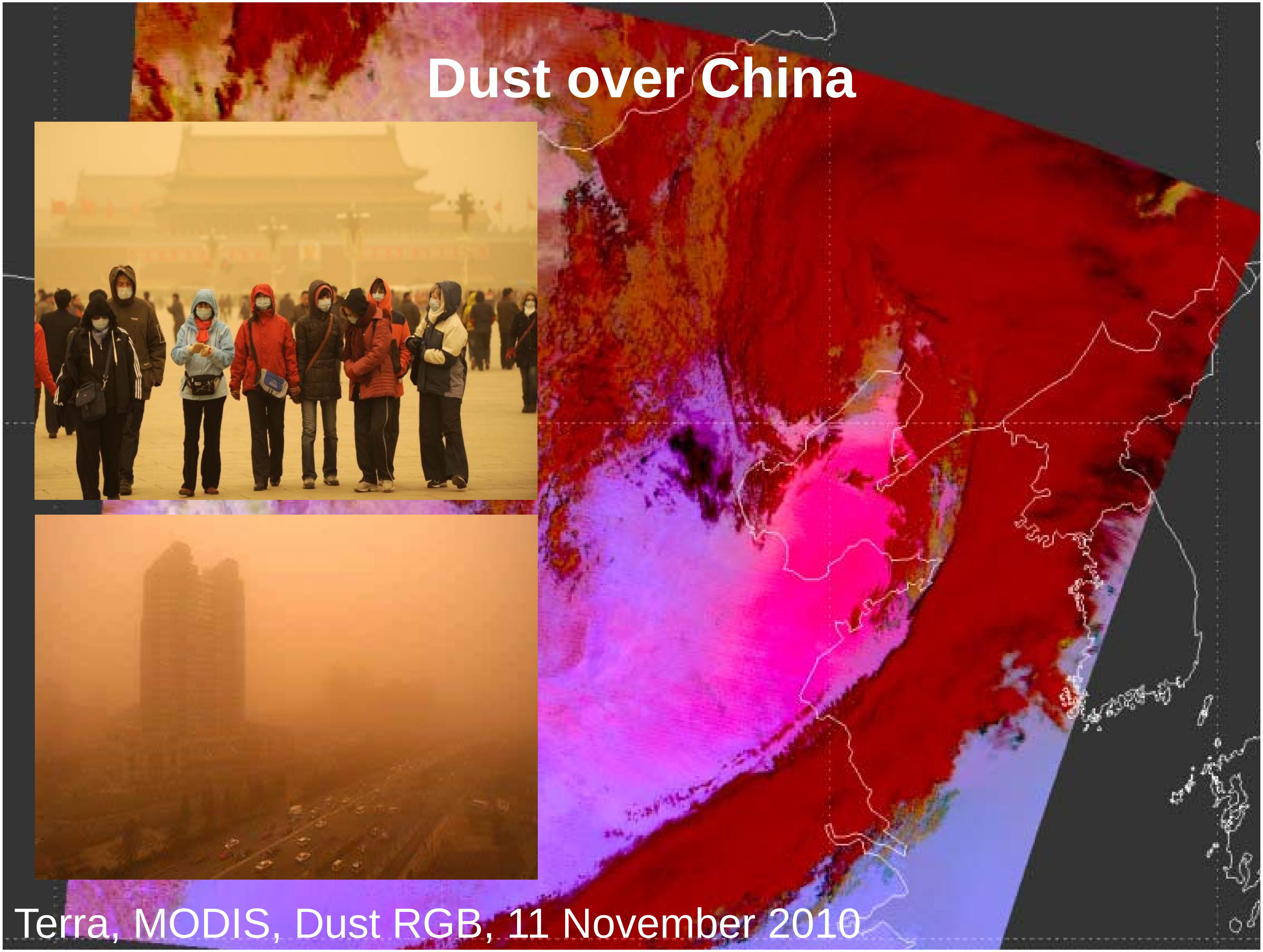


**RGB**
**24-hour**
**Ash**
**Microphysics**
**Global View**

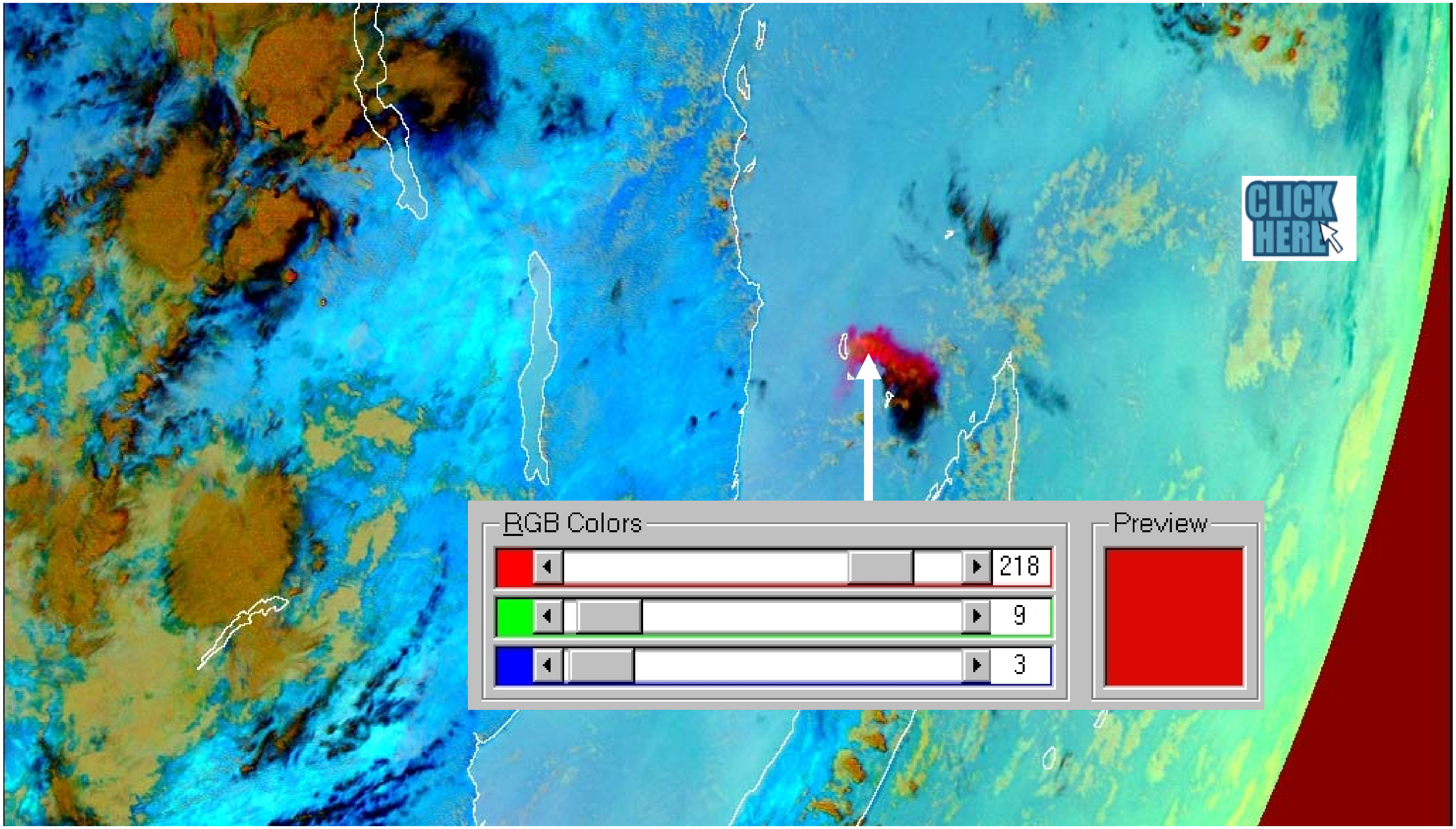
**MSG-1**
**25 November 2005**
**09:00 UTC**

# Dust over China



Terra, MODIS, Dust RGB, 11 November 2010

# Example: Volcanic Ash & SO2




MSG-1, 25 November 2005, 09:00 UTC

# RGB 24-hour Dust Microphysics:

## Interpretation of Colours for High-level Clouds

Cold, thick, high-level clouds

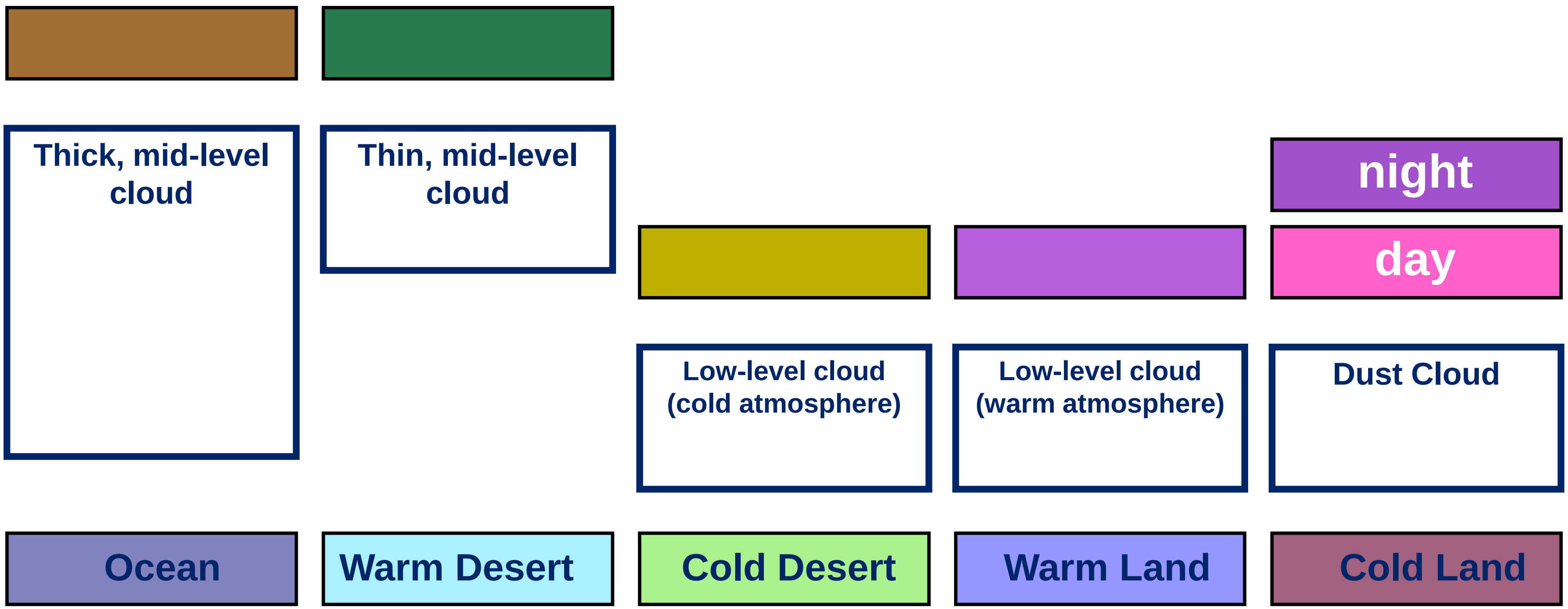
Thin Cirrus clouds / Contrails

over vegetated land / ocean    over sand desert

Ocean | Warm Desert | Cold Desert | Warm Land | Cold Land

# RGB 24-hour Dust Microphysics:

## Interpretation of Colours for Low/Mid-level Clouds



# 2. RGB Airmass

**R = Difference WV6.2 – WV7.3**
*** moisture/temperature profile**

**G = Difference IR9.7 – IR10.8**
*** Ozone content (O3-rich polar, O3-poor subtropical), Tsurf, Sat. Viewing**

**B = Channel WV6.2**
*** moisture/temperature profile**

*** Physical Interpretation (for cloud free situation)**

# 2. RGB Airmass

devised by: J. Kerkmann

| | |
|---|---|
| **Applications:** | Rapid Cyclogenesis,<br>PV Analysis, Deformation Zone & Jets |
| **Area:** | Full MSG Viewing Area (limb cooling) |
| **Time:** | Day and Night |
| **Users:** | most European NMSs, South Africa, Oman, Israel, NOAA/NASA |



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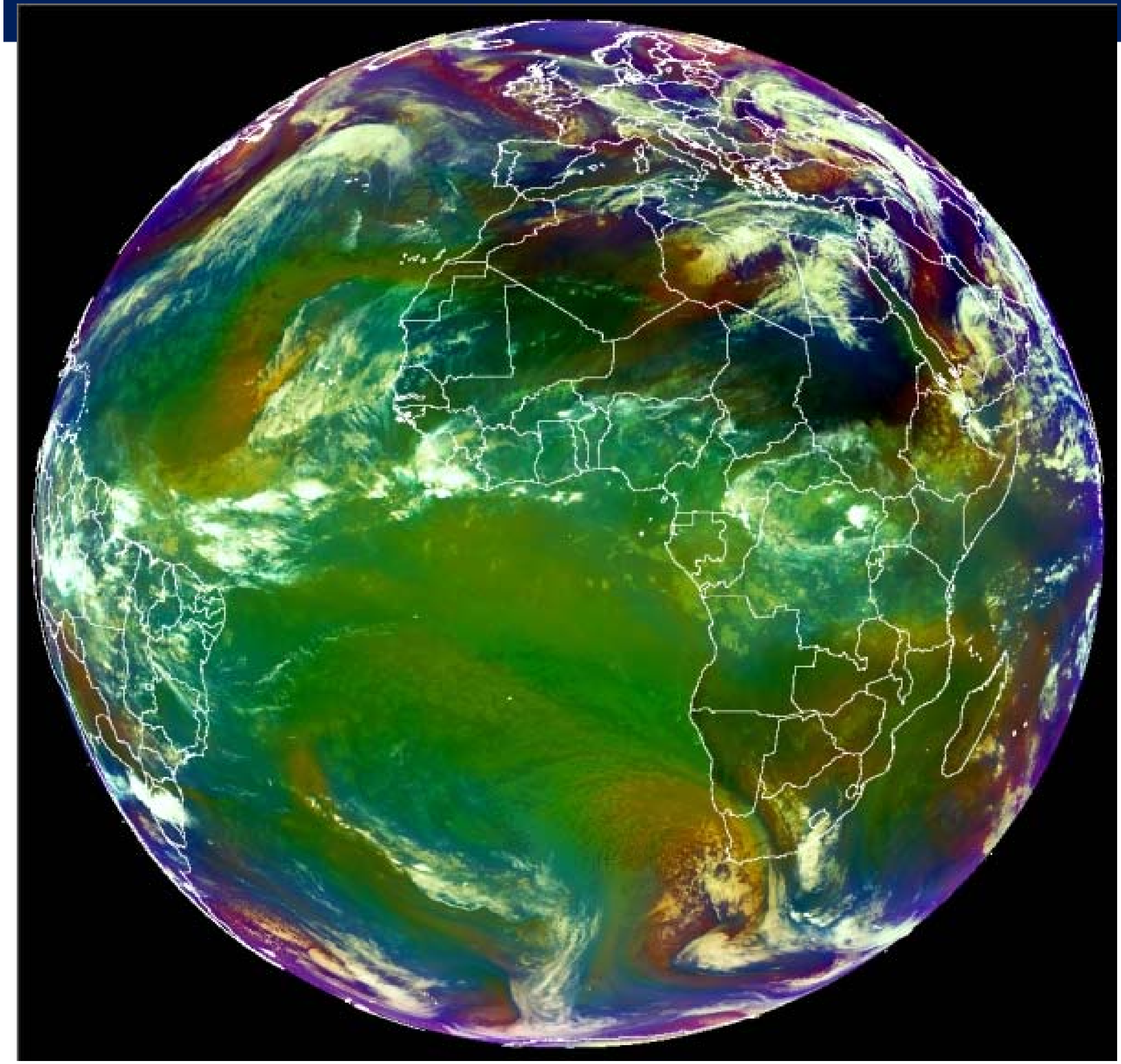
# 2. RGB Airmass

devised by: J. Kerkmann

## Recommended Range and Enhancement:

| Beam | Channel | Range | Gamma |
|---|---|---|---|
| **Red** | WV6.2 - WV7.3 | -25 … 0 K | 1.0 |
| **Green** | IR9.7 - IR10.8 | -40 … +5 K | 1.0 |
| **Blue** | WV6.2 | +243 … +208 K | 1.0 |

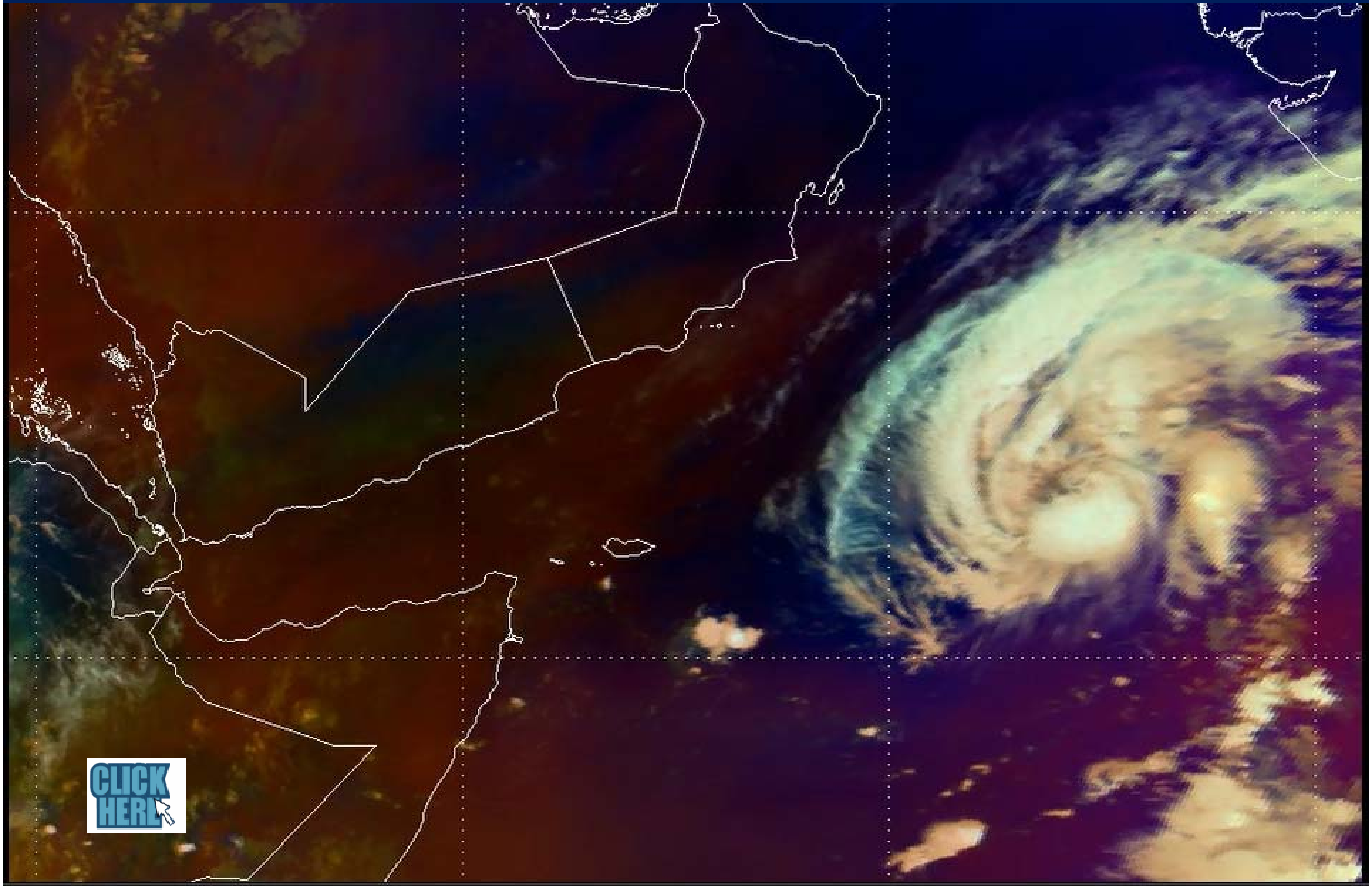


# RGB Airmass Global View

**Note:** warm airmasses seen at a high satellite viewing angle appear with a blueish colour (limb cooling effect) !

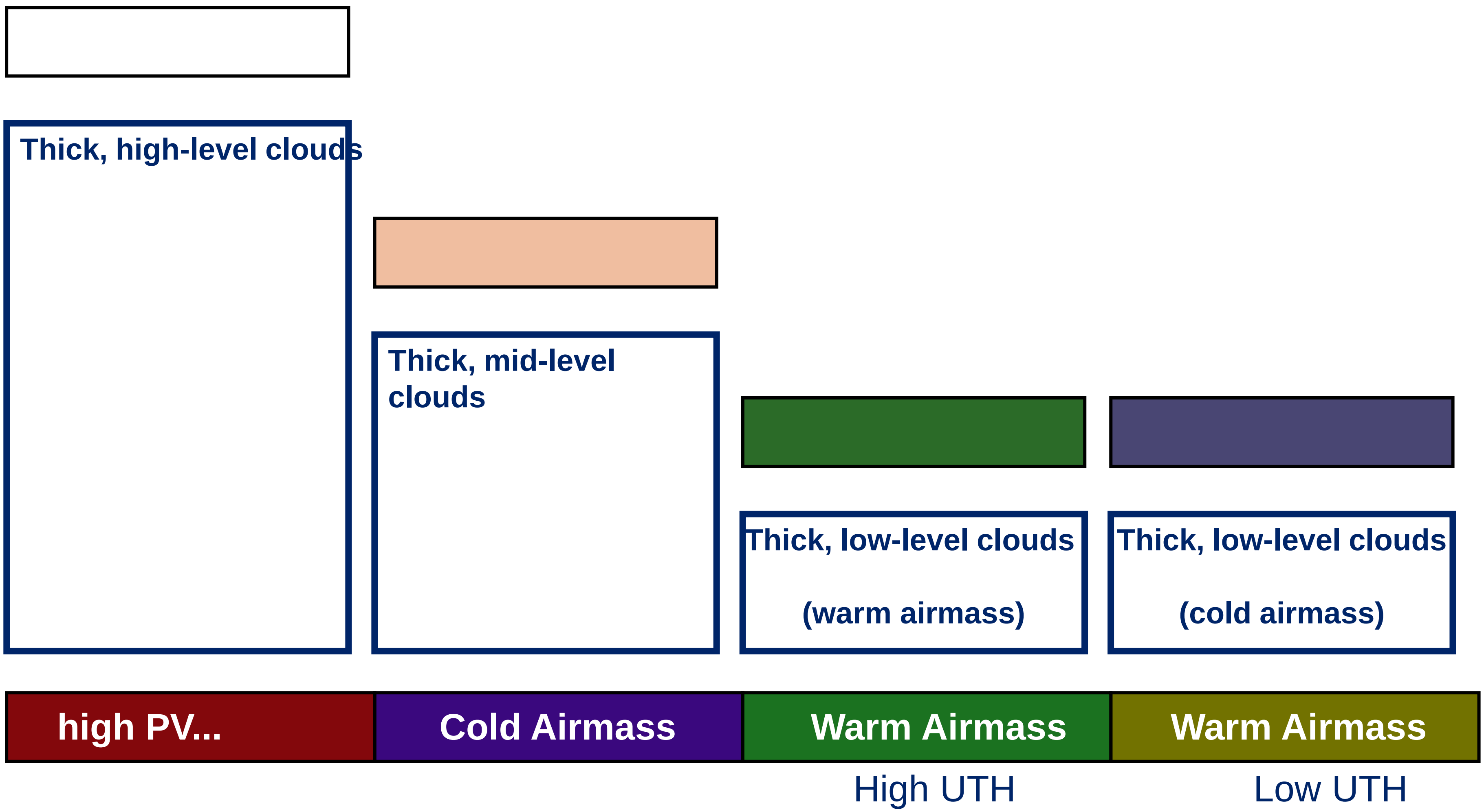
**MSG-1**
**19 April 2005**
**10:00 UTC**

# RGB Airmass: Tropical Cyclone Chapala



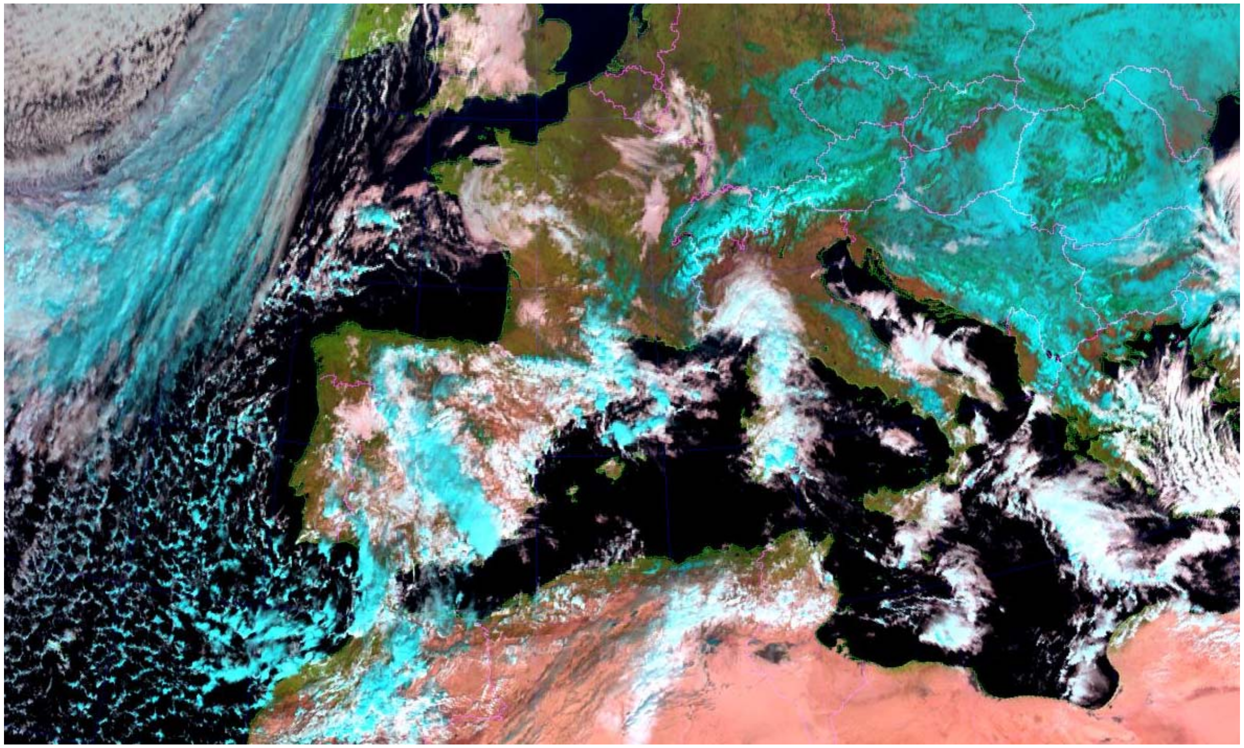
# RGB Airmass:

## Interpretation of Colours



# Some words of caution on RGB use

Can different features have the same colour, making them hard to decipher ?



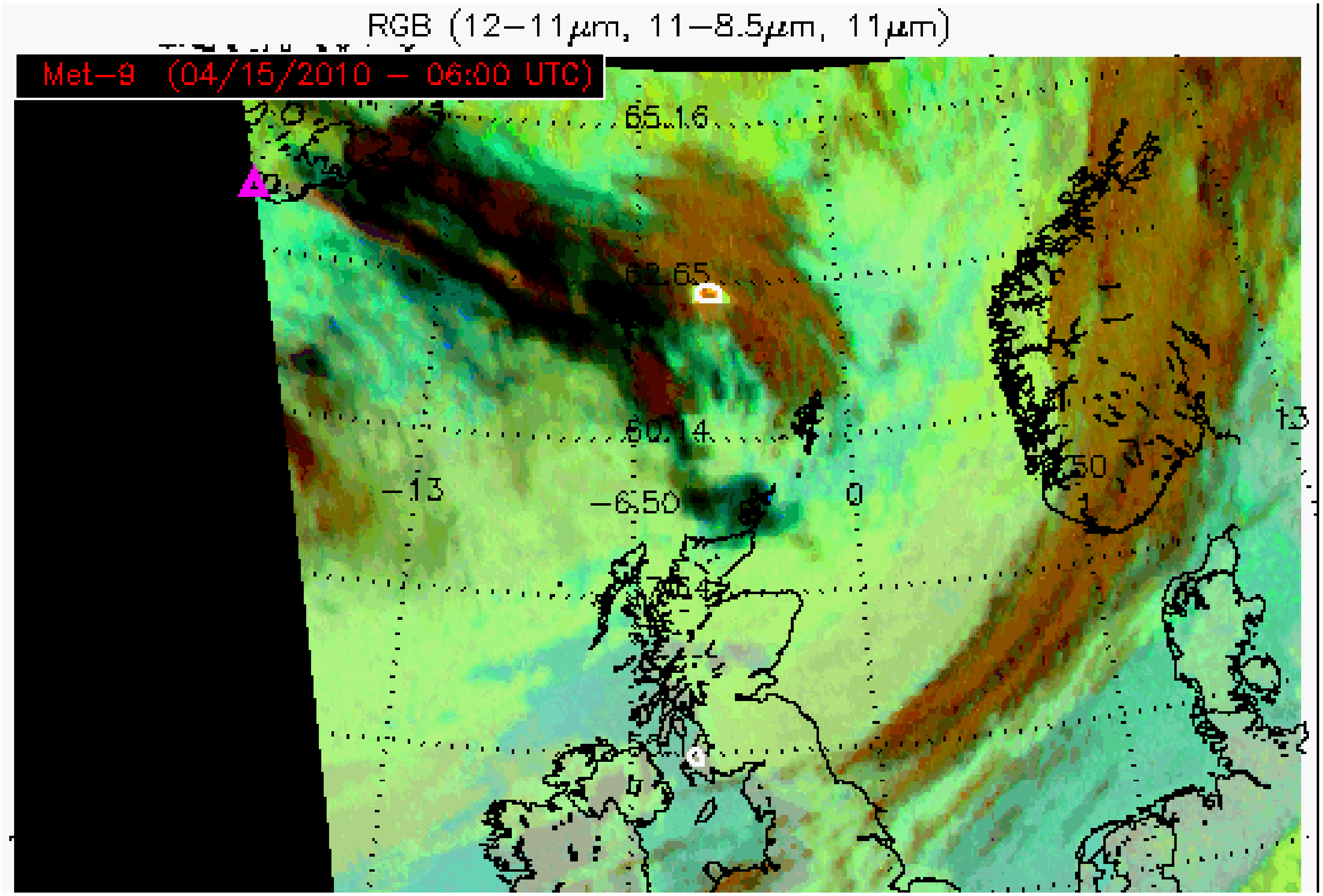
Yes. Just think of the ambiguity between high clouds and snow cover on the natural colour RGB. It’s hard to distinguish them because they are both cyan.

# Some words of caution on RGB use

How do RGB products differ from single colour enhancements and quantitative products?

An important difference to quantitative products is that RGB products are much easier to implement and they preserve the "natural look" of images by retaining original textures (no artifacts, no artificial jumps or boundaries). Also, spatial and temporal continuity allow for smooth animation of RGB product sequences (quantitative products are sometimes quite difficult to animate). Furthermore, quantitative products are often generated at a reduced (coarser) horizontal/temporal resolution, while RGB products are (should be) at full time/space resolution!

# Example: Ash Clouds (15 April 2010)




Source: M. Pavolonis

**Derived product overlaid on Ash RGB**



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# Some words of caution on RGB use

## What is the quality of RGB images?

The quality of RGB images is directly (one to one) linked to the quality of the level 1.5 input images. Users should therefore be aware of typical problems with single channel images.  One example is the problem with IR3.9 and WV6.2 images during eclipse season, which affects the images around midnight. The straylight problem of these channels is directly reflected in the RGB images that make use of these channels, namely the Night Microphysics RGB (also called Fog RGB) and the Airmass RGB.



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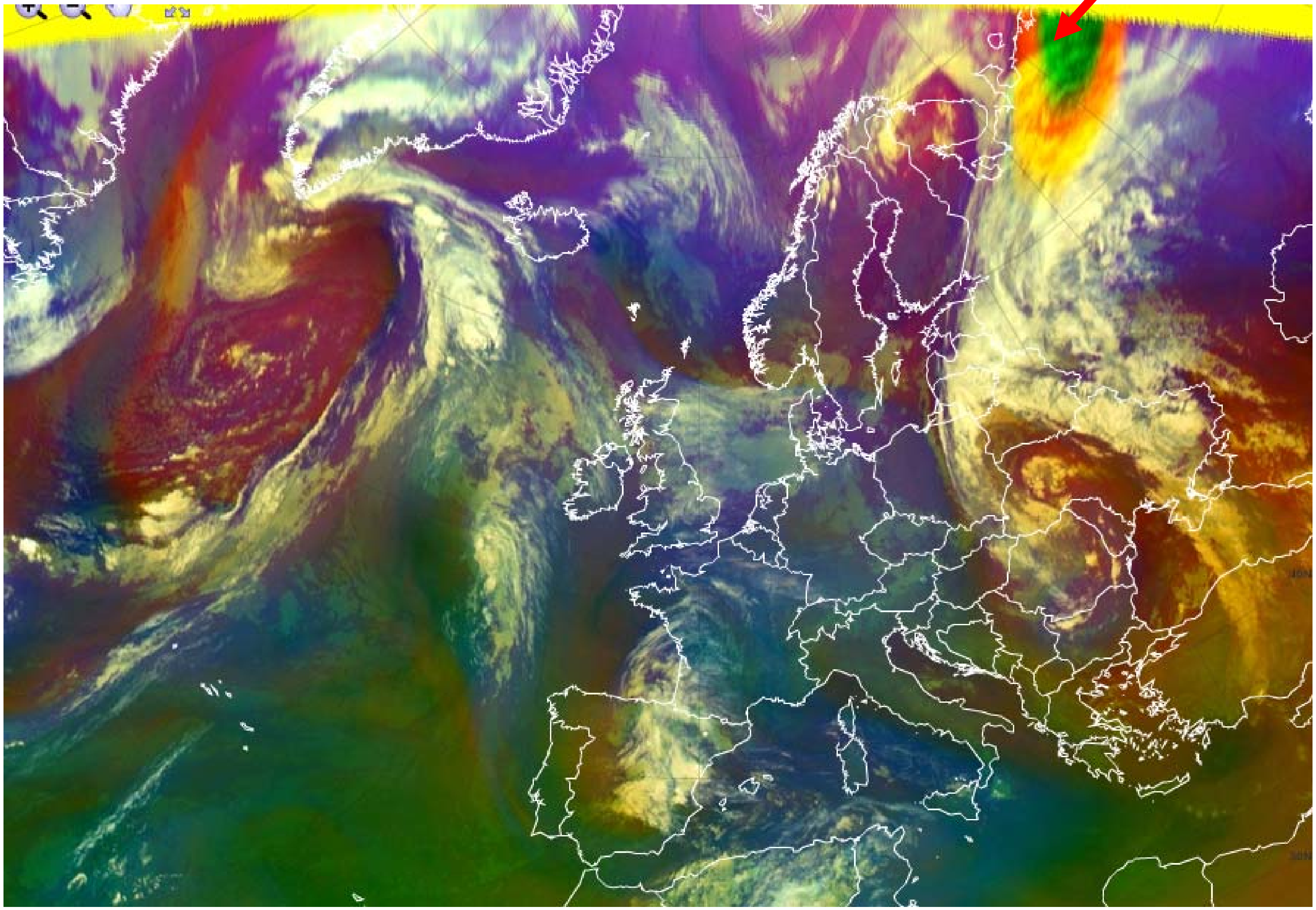
# Training Example

Sun stray light
(during eclipse)



**2 September 2010, 00:00 UTC**



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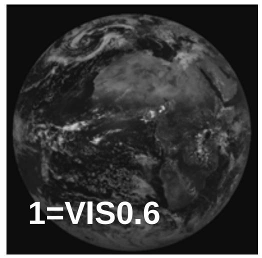
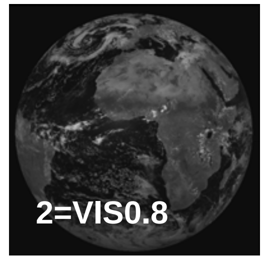
AOMSUC→ Tuesday morning: Presentation on the Status of the EUMETSAT Satellite Programmes by Dr. Ken Holmlund

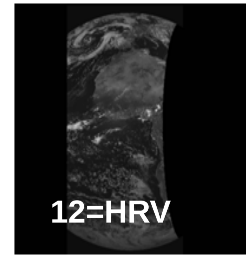
# PART 5:

# METEOSAT THIRD GENERATION (MTG)

# Meteosat Second Generation (MSG)

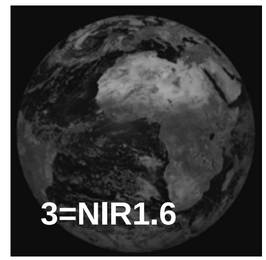


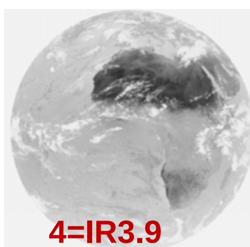



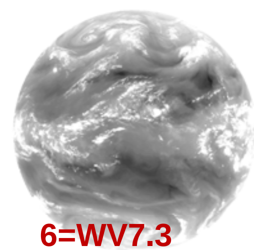

1.0 km

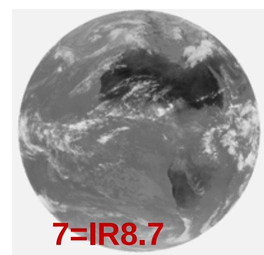
Solar
3.0 km



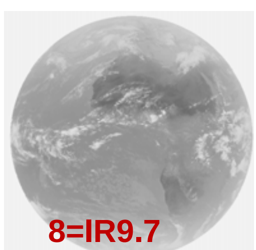



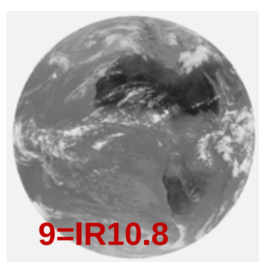


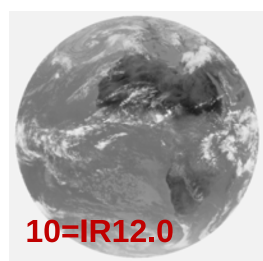


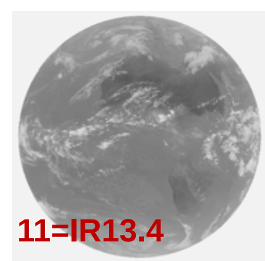




Thermal
3.0 km



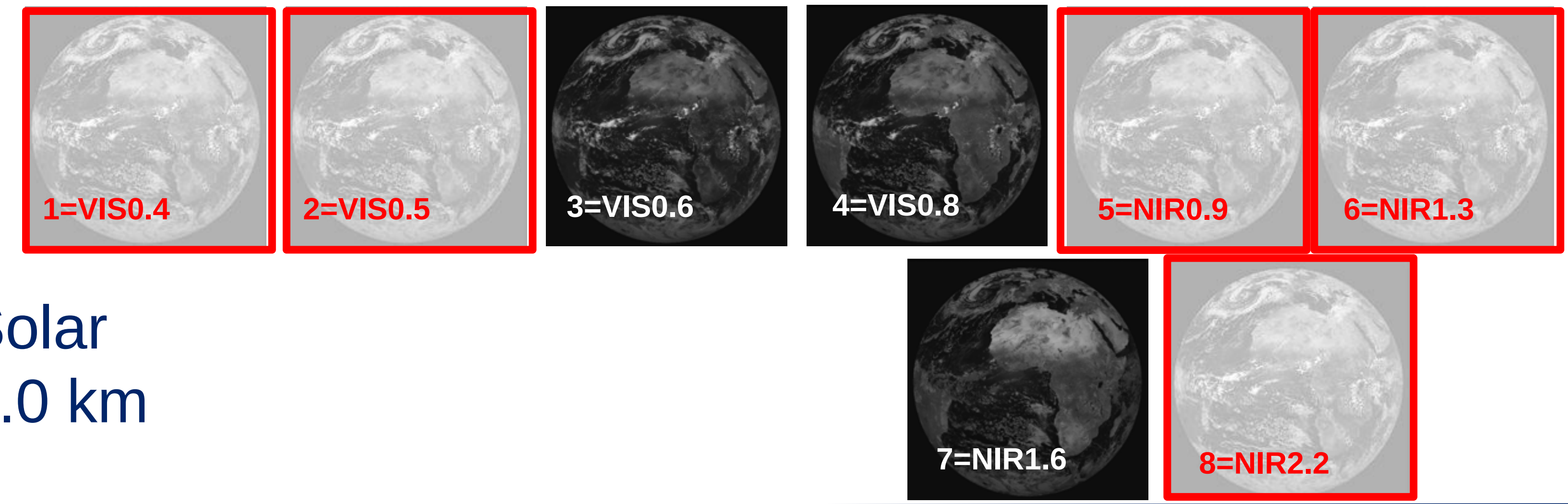



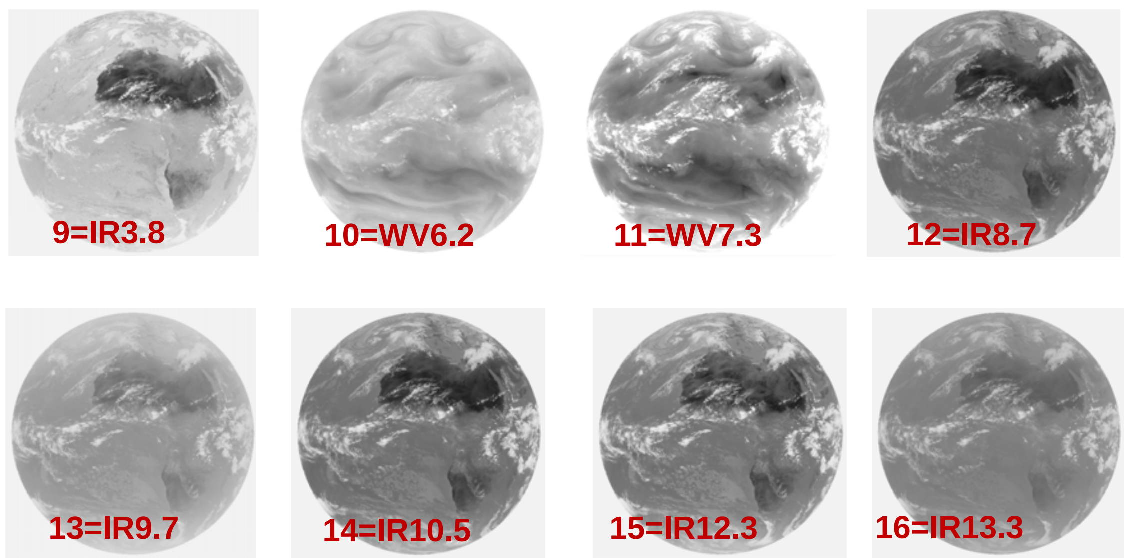



# Meteosat Third Generation (MTG)

Solar
1.0 km




Thermal
2.0 km






EUMETSAT

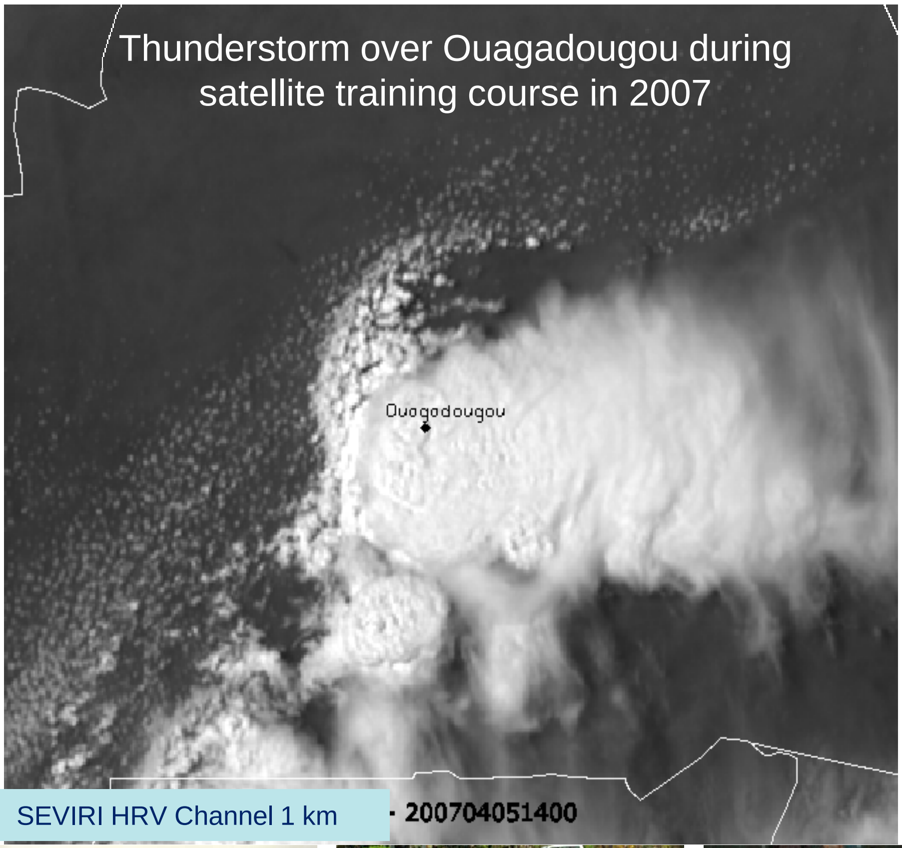
# FCI – Benefits from higher resolution

MTG FCI:

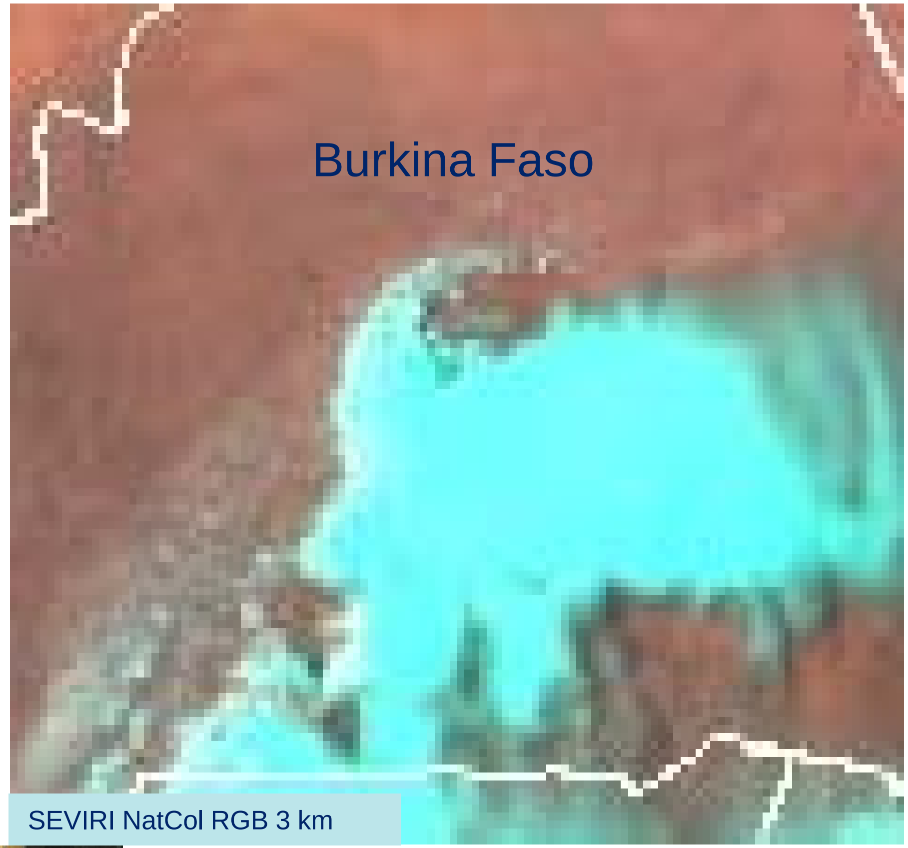
- Better spatial resolution
  1. Full Disk Scan: IR 2 km, VIS 1 km
  2. Regional Scan: IR 1 km, VIS 0.5 km

- Better time resolution
  1. Full Disk Scan: 10 min
  2. Regional Scan: 2.5 min

# MSG: only one HRV channel @ 1 km sampling




SEVIRI HRV Channel 1 km




SEVIRI NatCol RGB 3 km

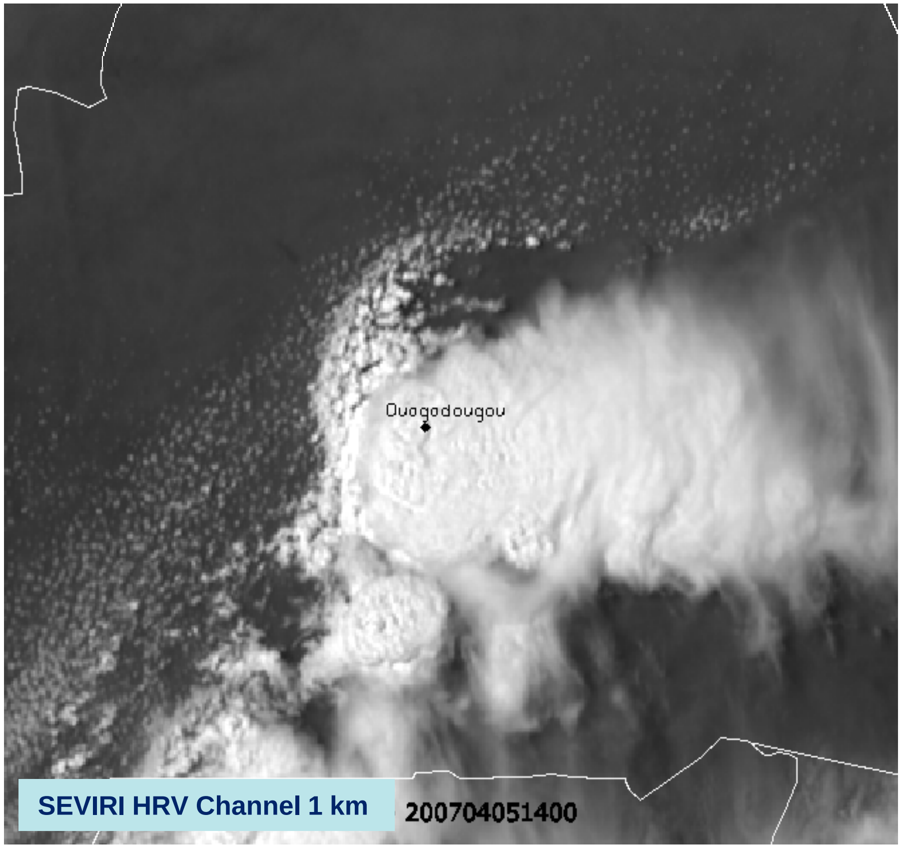
Courtesy: H. Verschuur

**5 April 2007, 14:00 UTC**

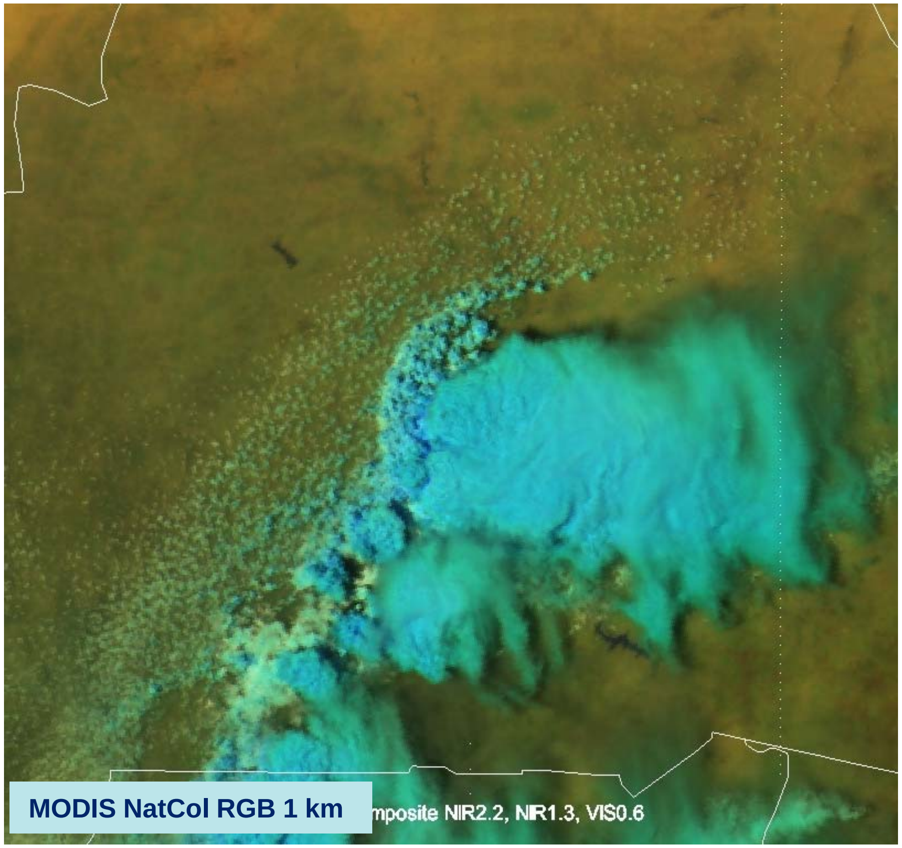
EUMETSAT

# MTG Improvements: 8 solar channels @ 1 km sampling

## SEVERI (14:00 UTC)




## MODIS (13:25 UTC)



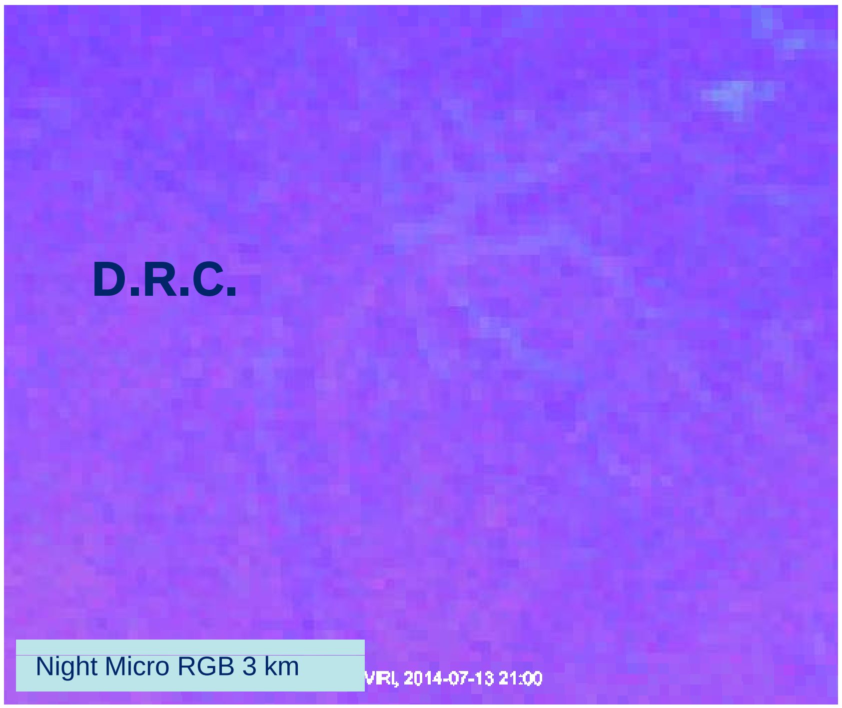

**5 April 2007**



EUMETSAT

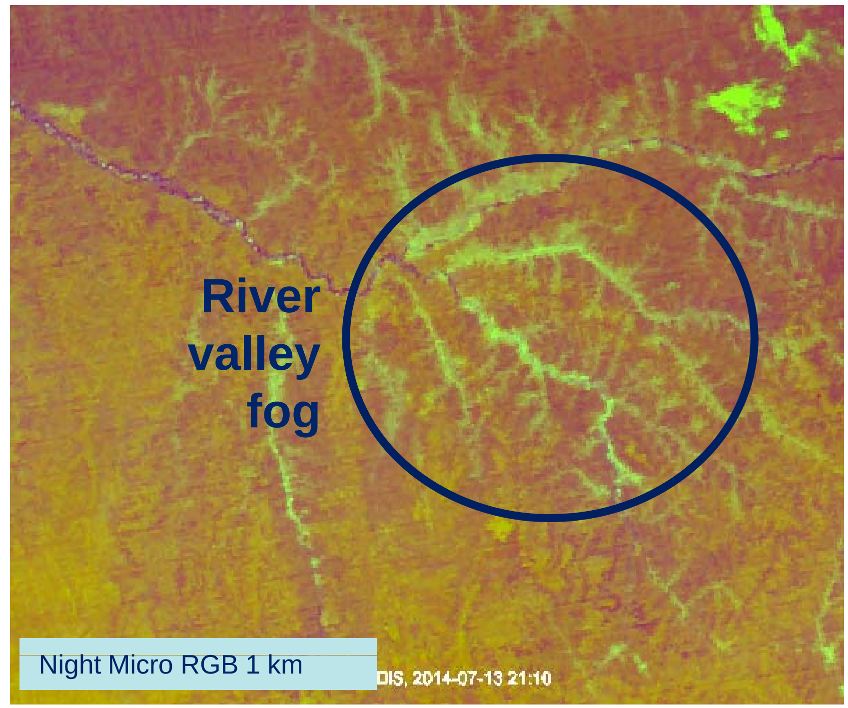
# MTG Improvements: fog monitoring

## SEVERI (21:00 UTC)




Shallow river valley fog often not detected in MSG (too thin and too small area)

## MODIS (21:10 UTC)




**13 July 2014**

# FCI – Benefits from new Channels

- The 0.91 µm channel will provide during daytime total column precipitable water especially over land surfaces.
- The 2.26 µm channel will provide the capability for an improved retrieval of cloud microphysics.
- The 0.444 µm and the 0.51 µm channels will support true colour images and permit surpassing current aerosol retrievals especially over land – also an important contribution to air quality monitoring
- The 1.375 µm channel will improve detection of very thin cirrus clouds not seen by the current system. If not detected, errors are introduced in all clear sky products.
- The higher spatial resolution (1 km and 2 km) of the 3.8 µm channel will improve fire detection and, via its extended dynamical range (from 350 K to 450 K), the quality of products as Fire Radiative Energy (FRE) – a climate relevant product directly related to the $CO_2$ production of active fires.

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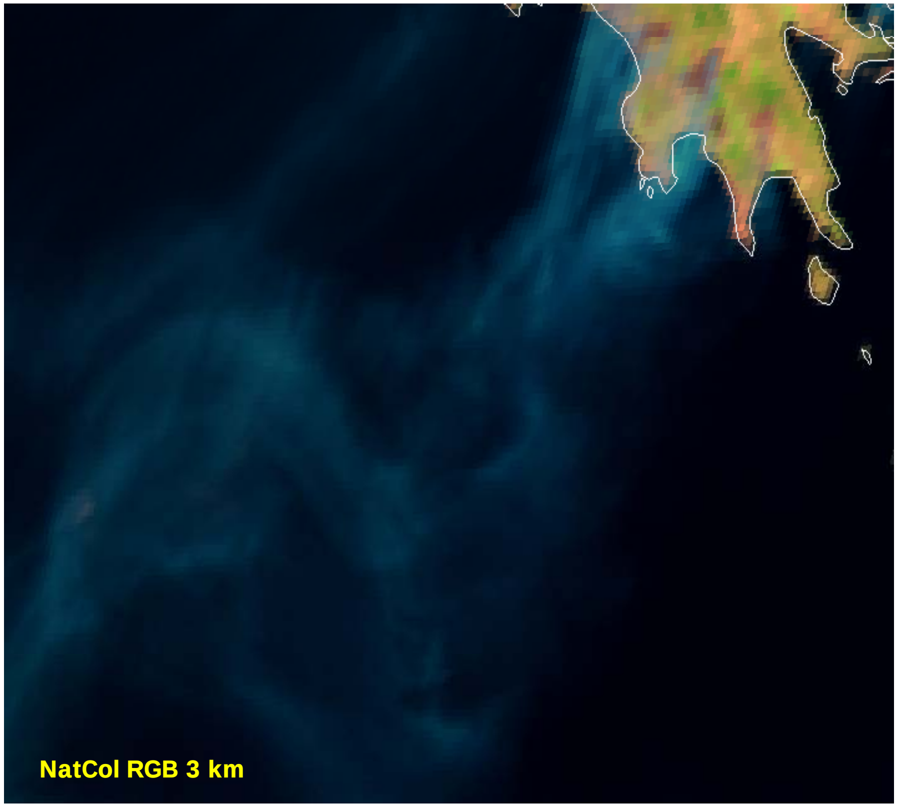
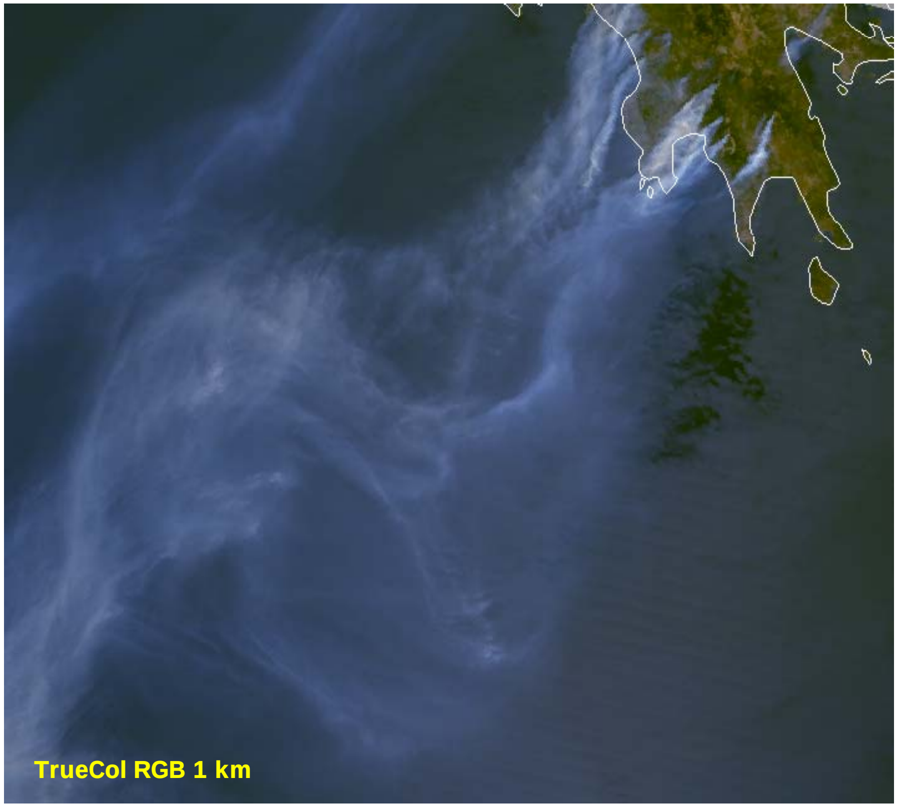
# MTG Improvements: smoke detection

## SEVERI (11:00 UTC)




## MODIS (09:35 UTC)




**26 August 2007**

Smoke is transparent in IR !
More solar channels needed !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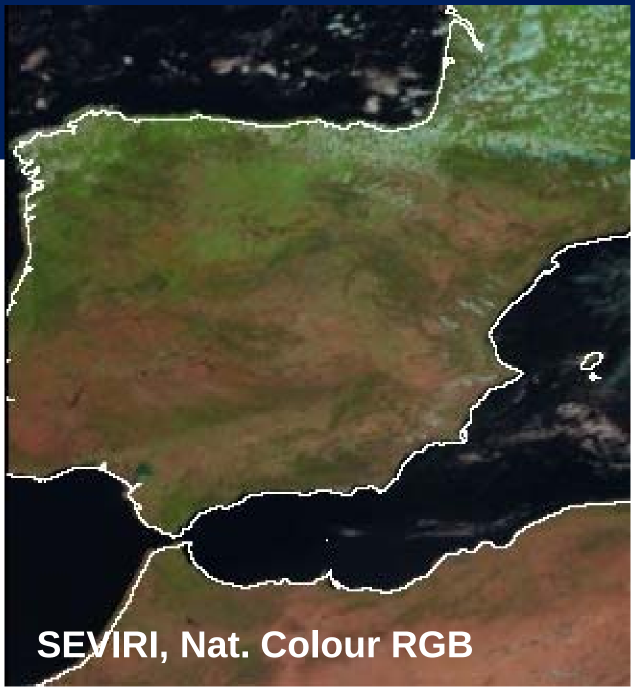
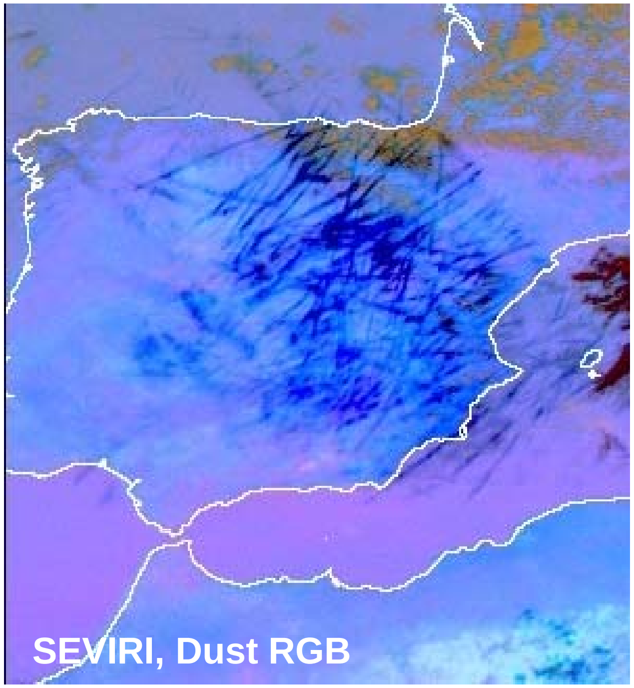
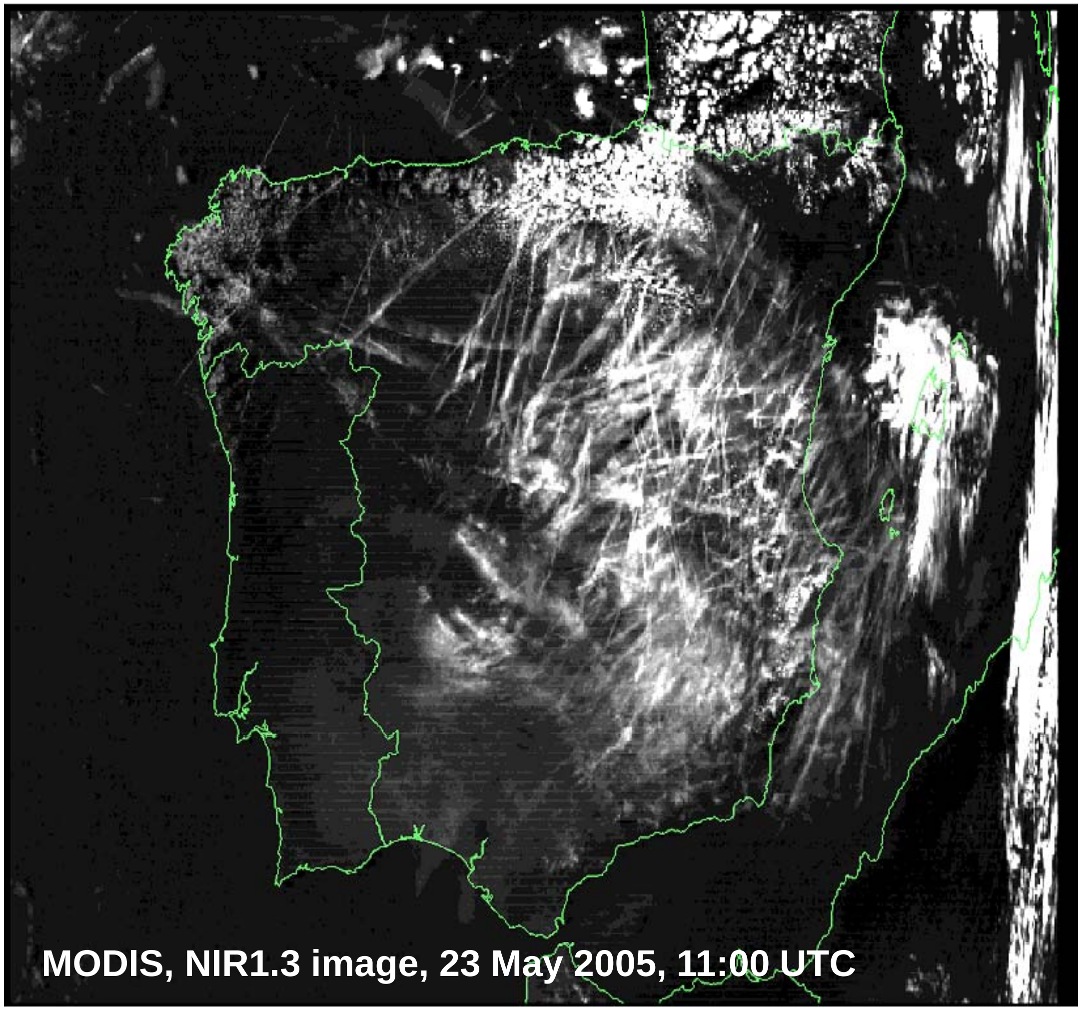
# NIR1.3: One Example




courtesy D. Rosenfeld, Univ. Jerusalem

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# Summary: RGBs are...

- Generally made from three or more individual or differenced spectral channels; each is assigned to a primary color (red, green, or blue); the final product highlights atmospheric and surface features that are hard to distinguish with single channel images alone
- Provide intuitive, realistic looking products that can reduce ambiguities and simplify interpretation
- In some situations, different features can have the same color or the same feature can appear in different colors. One way to handle this is to animate the products
- Can be overlaid with quantitative information, such as model data or other observational data, enabling more sophisticated analysis and interpretation
- Are increasingly available online and in near real-time
- Future satellite imagers will have increasing numbers of spectral channels, allowing for more RGBs and new applications

# RGBs on the Web (near real-time)

- SEVIRI RGBs: EUMETView (OGC Web Map Server)

- SEVIRI RGBs: EUM Real-time Images
- SEVIRI RGBs: Eumetrain ePort
- AHI RGBs: MSC of JMA

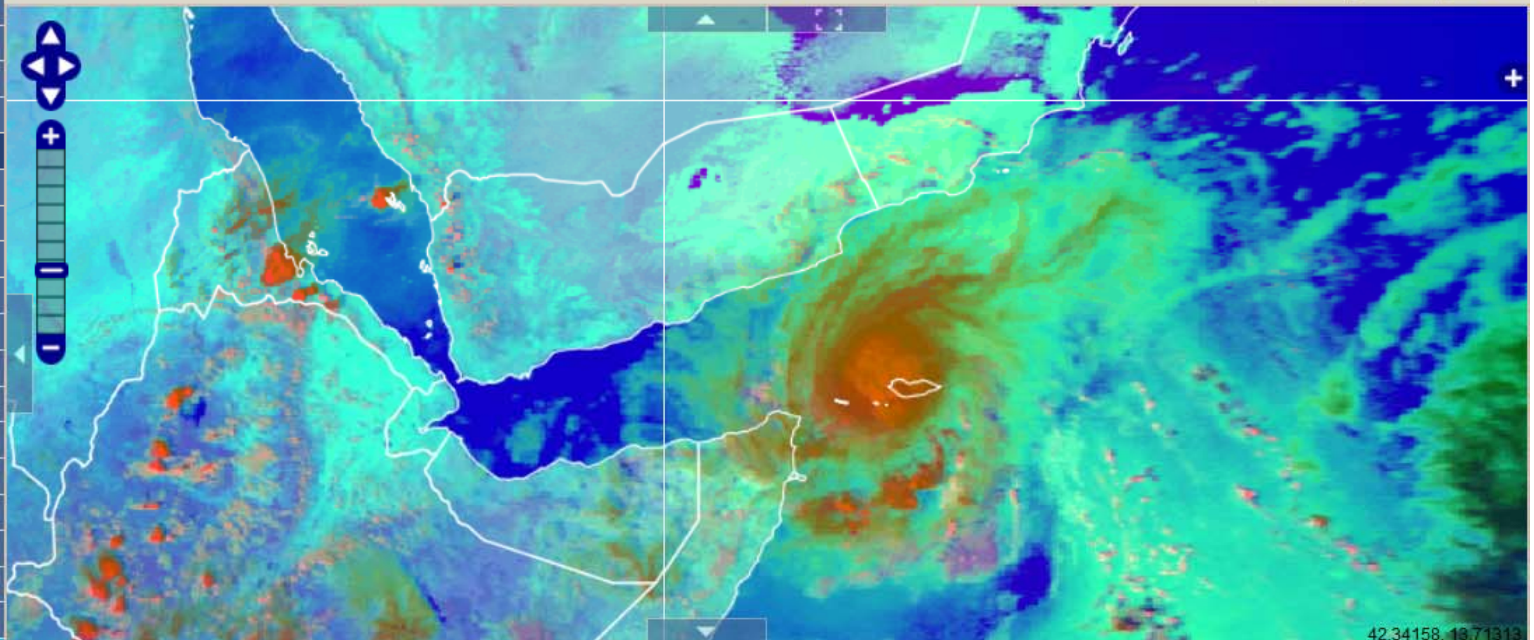
# EUMETView

EUMETSAT

MONITORING WEATHER AND CLIMATE FROM SPACE

- METEOSAT IODC
  - IMAGERY
    - IR 11.5
    - VIS 007
    - WV 064
- METEOSAT 0 DEGREE
  - IMAGERY
    - IR 10.8
    - IR 03.9
    - VIS 006
    - WV 062
  - VISUALISED PRODUCTS
  - RGB COMPOSITES
    - AIRMASS
    - ASH
    - CONVECTION
    - DUST
    - EVIEW
    - FOG
    - MICROPHYSICS
    - NATURAL COLOR
    - SNOW
- METOP

Time: 2015-11-08 13:00:00 Region:



DAY MICROPHYSICS RGB - MSG - 0 DEGREE

The Day Microphysics RGB (Red, Green, Blue) was inherited from Rosenfeld and Lensky (1998): the VIS0.8 reflectance in red approximates the cloud optical depth and amount of cloud water and ice; the IR3.9 solar reflectance in green is a qualitative measure for cloud particle size and phase, and the IR10.8 brightness temperature modulates the blue. This color scheme is useful for cloud analysis, convection, fog, snow, and fires. In this colour scheme water clouds that do not precipitate appear white because cloud drops are small, whereas large drops that are typical to precipitating clouds appear pink, because of the low reflectance at IR3.9 manifested as low green. Supercooled water clouds appear more yellow, because the lower temperature that modulate the blue component. Cold and thick clouds with tops composed of large ice particles, e.g., Cb tops, appear red. Optically thick clouds with small ice particles near their tops appear orange.

CONTACT US LEGAL INFORMATION SCALE = 1 : 12M

# Further Reading

- Eumetrain: Operational Use of RGBs
- Eumetrain: MSG Interpretation Guide
- Eumetrain: RGB Colour Interpretation Guide
- Comet: RGBs Explained
- EUMETSAT: Image Library
- EUMETSAT: Training Library

Thank you for your attention !

Feel free to contact our User Service Helpdesk at ops @eumetsat.int